STP – Spanning Tree Protocol

Cabrillo College

CIS 83

CCNA 3

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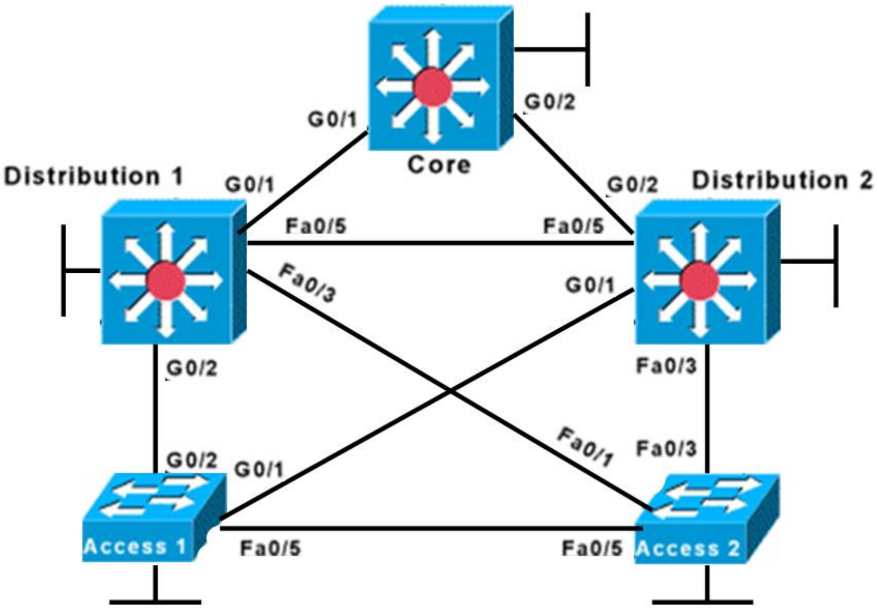
Fall 2006

Spanning Tree Protocol (STP)

- STP often accounts for more than 50 % of the configuration, troubleshooting, and maintenance headaches in real-world campus networks (especially if they are poorly designed).
- Complex protocol that is generally poorly understood.
- Radia Perlman – Developer of STP
- STP, RSTP and other features are discussed in greater detail in CIS 187 Multilayer Switching, CCNP 3.

More detail than you need to know ☺

- In this presentation we will discuss much of the detail of STP.
- Much of the detail is not needed for CCNA, however we will discuss it to get a better understanding of how STP operates.
- I am not concerned that you completely understand or remember the detail, but rather get an appreciation for what STP is doing.
- Even with the added detail, much more detail has been intentionally left out and will be discussed in CIS 187 (CCNP 3).



Configuring STP

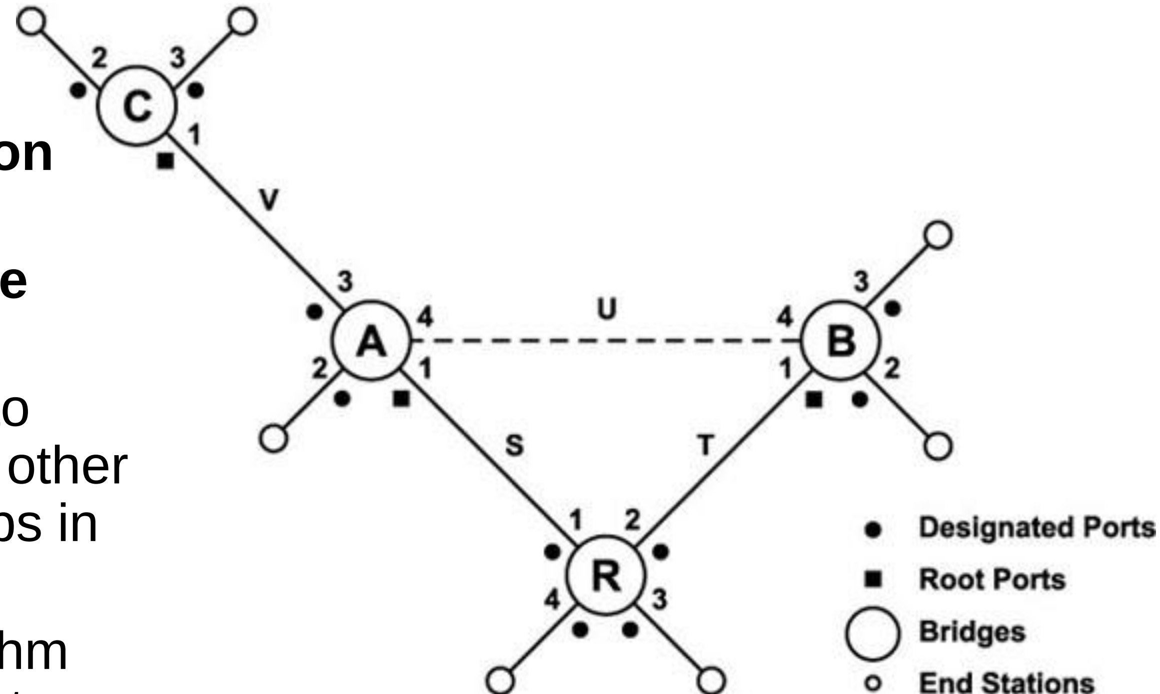
- By default, STP is enabled for every port on the switch.
- If for some reason STP has been disabled, you can reenable it.
- To re-enable STP, use the

Switch(config)#spanning-tree vlan *vlan-id*

- To disable STP, on a per-VLAN basis:

Switch(config)#no spanning-tree vlan *vlan-id*

Spanning Tree Protocol (STP)



- STP is a **loop-prevention protocol**
- Uses the **Spanning Tree Alogithm**
- STP allows L2 devices to communicate with each other to discover physical loops in the network.
- STP specifies an algorithm that L2 devices can use to create a *loop-free logical* topology.
- STP creates a tree structure of loop-free leaves and branches that spans the entire Layer 2 network.

Redundancy Creates Loops

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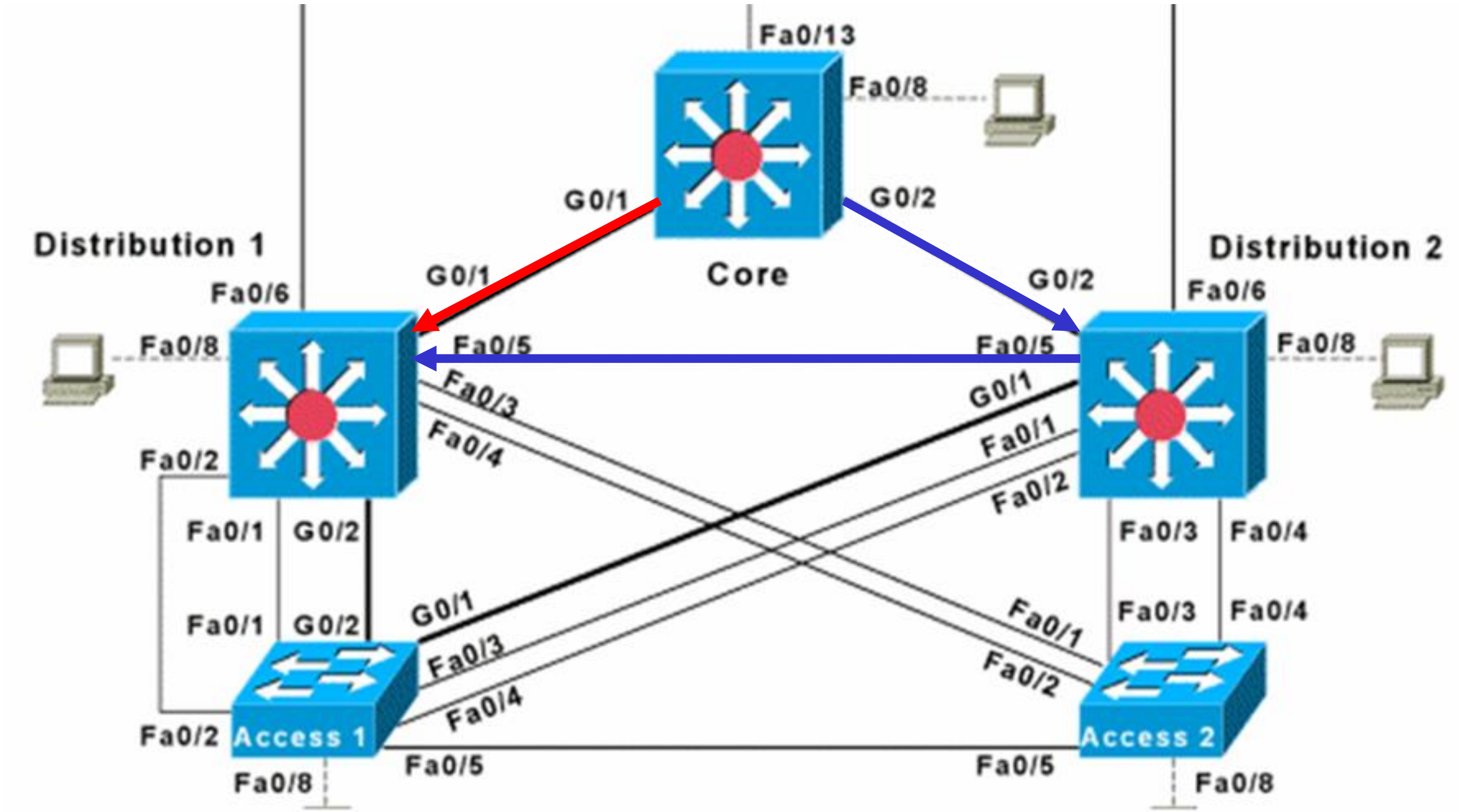
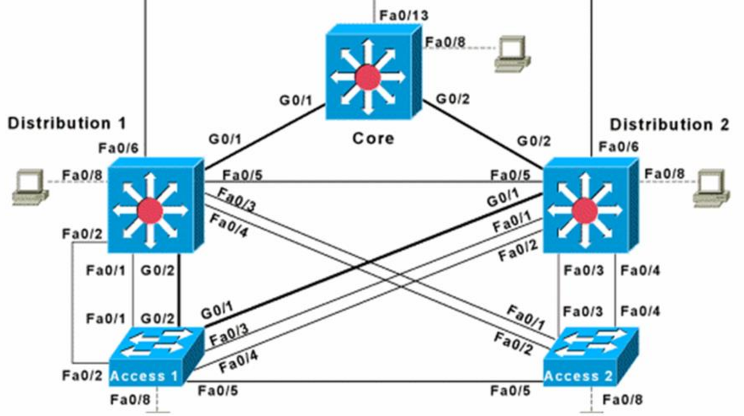
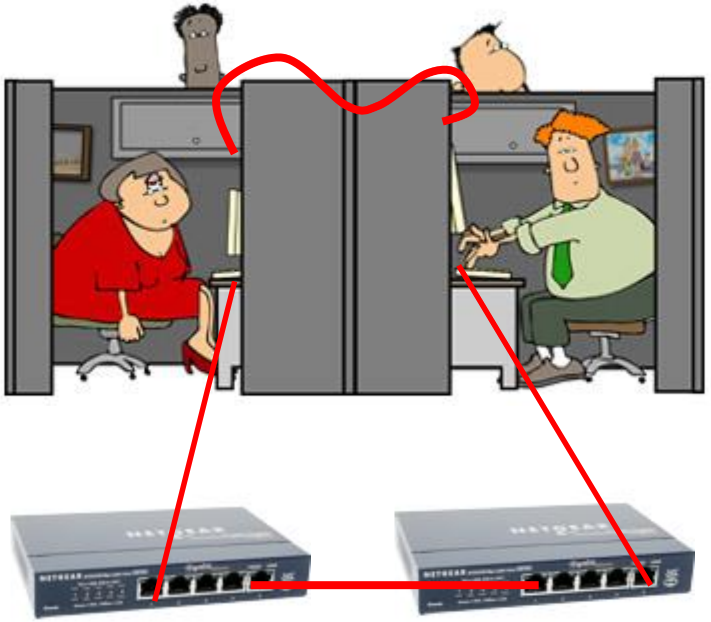


Spanning Tree – Only for Loops



- Loops may occur in your network as part of a a design strategy for redundancy.
- STP is not needed if there are no loops in your network.
- However, DO NOT disable STP!
- Loops can occur accidentally from network staff or even users!

Two users interconnecting the switches in their cubicles.



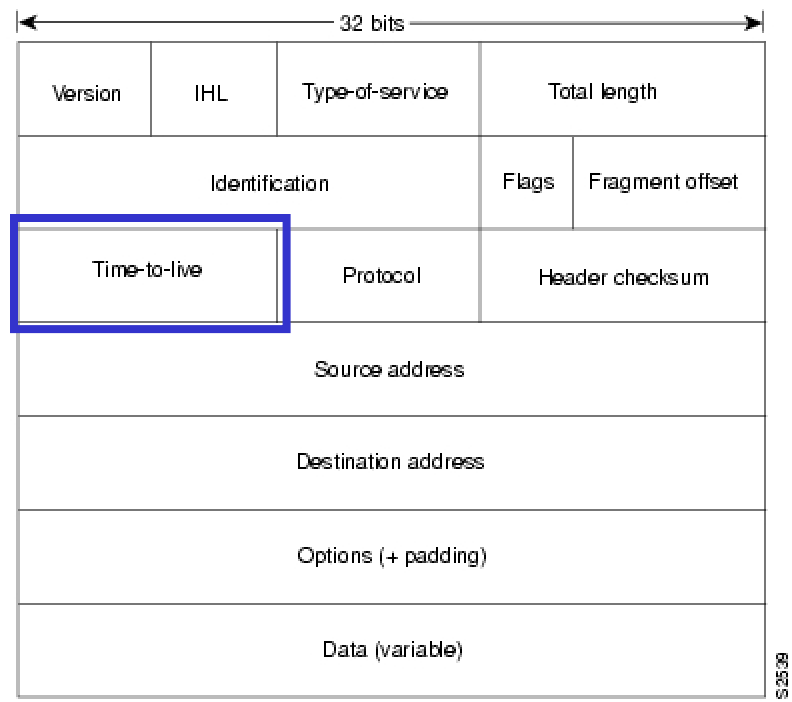
L2 Loops

- Broadcasts and Layer 2 loops can be a dangerous combination.
- Ethernet frames have no TTL field
- After an Ethernet frame starts to loop, it will probably continue until someone shuts off one of the switches or breaks a link.

Ethernet Frame Format

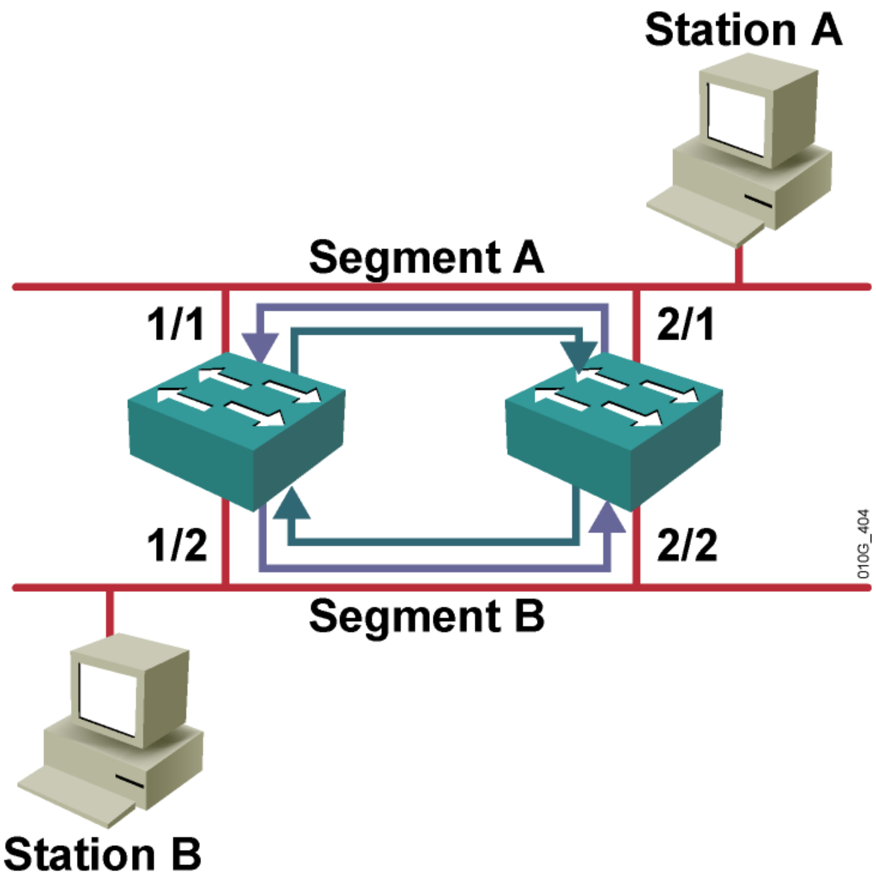
64	48	48	16		32	8
Preamble	Destination address	Source address	Type field	Data payload	CRC	Postamble

IP Packet



L2 Loops - Flooded unicast frames

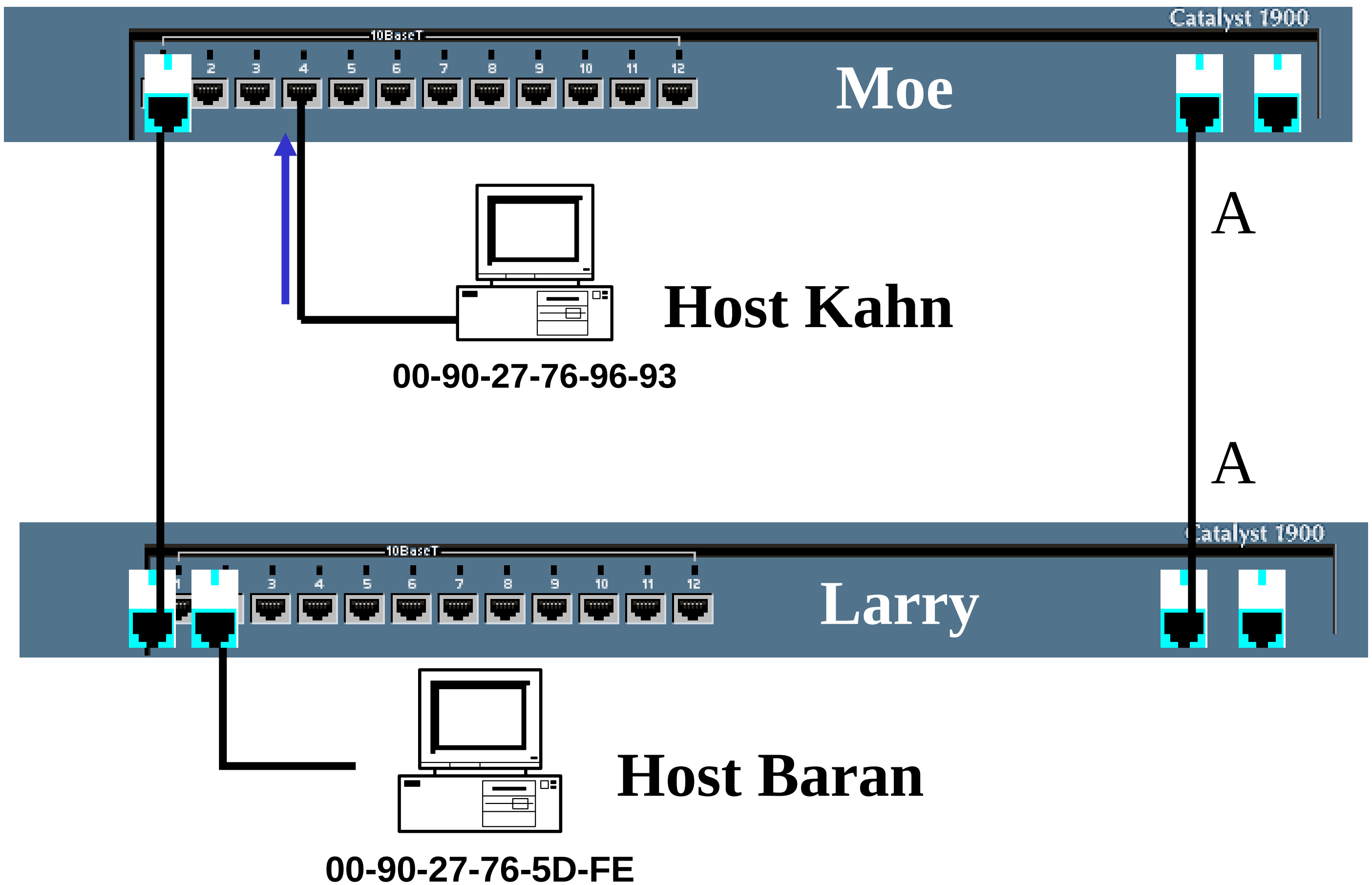
- Bridge loops can occur any time there is a redundant path or loop in the bridge network.
- The switches will flip flop the bridging table entry for Station A (creating extremely high CPU utilization).
- **Bridge Loops can cause:**
  - Broadcast storms
  - Multiple copies of Ethernet frames
  - MAC address table instability in switches



Unknown Unicast

Switch Moe learns Kahns' MAC address.

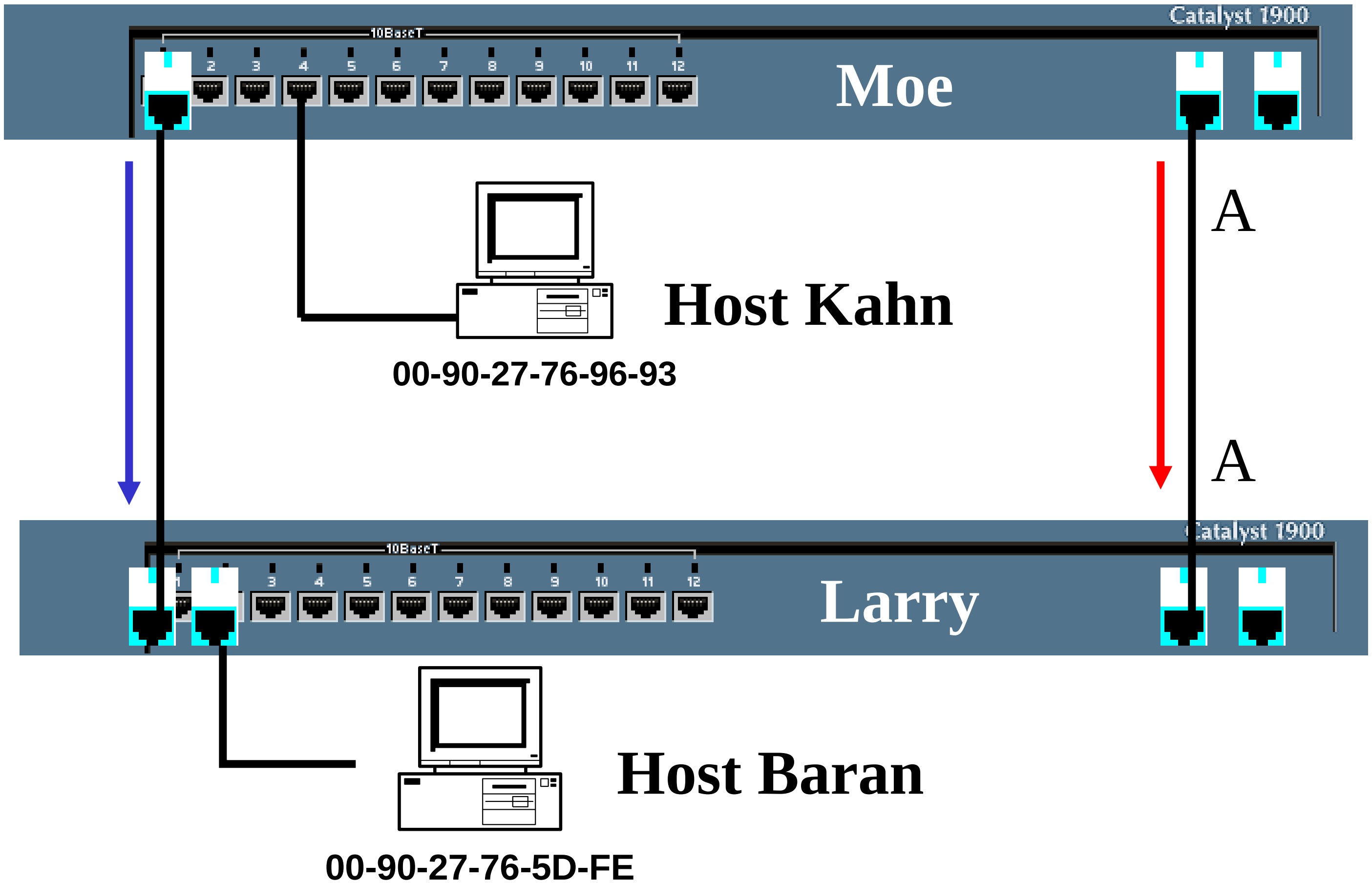
```
SAT (Source Address Table)
Port 4:  00-90-27-76-96-93
```



Unknown Unicast

- Destination MAC is an unknown unicast, so Moe floods it out all ports.

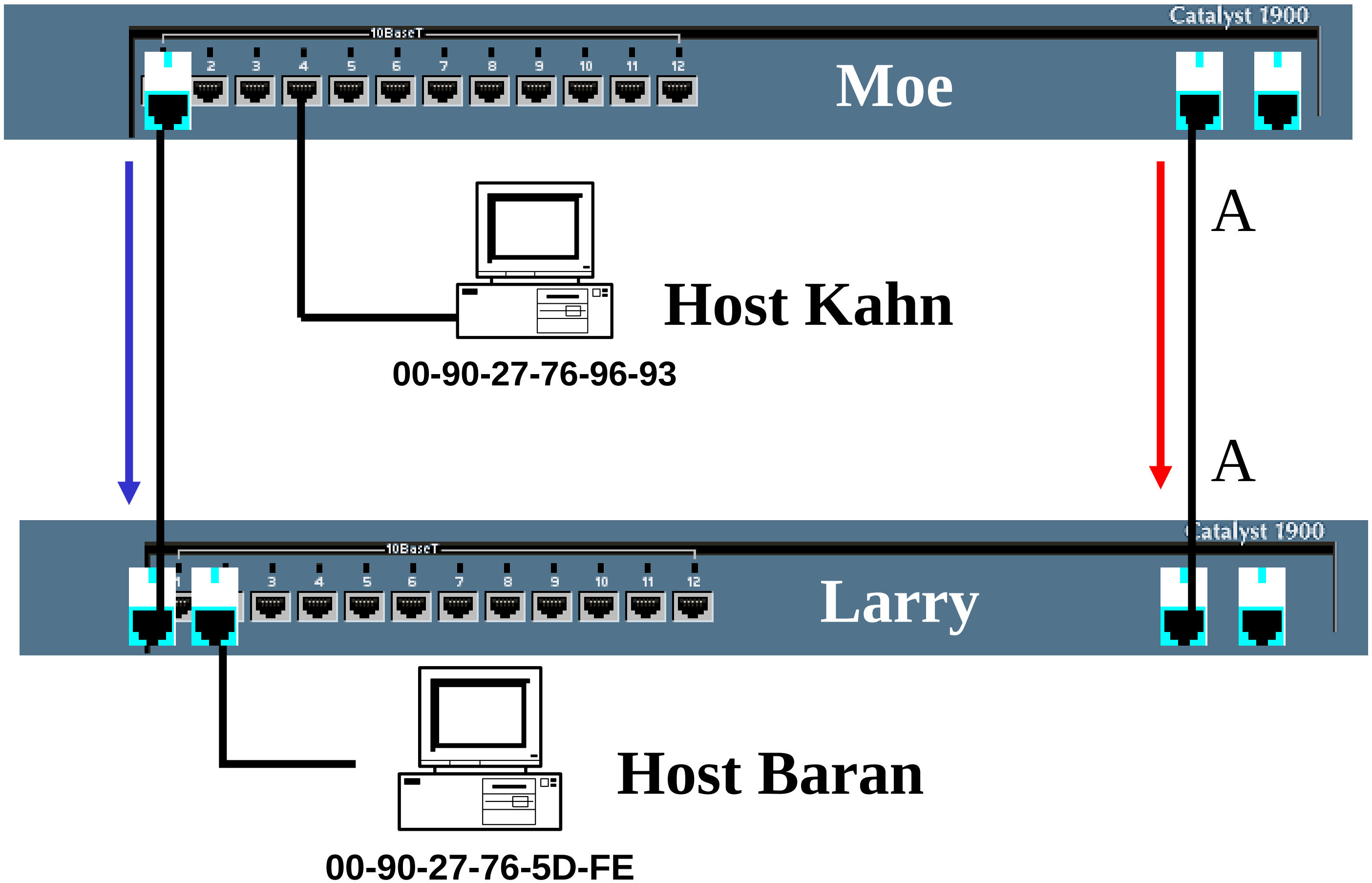
```
SAT (Source Address Table)
Port 4:  00-90-27-76-96-93
```



Unknown Unicast

- Destination MAC is an unknown unicast, so Moe floods it out all ports.

SAT (Source Address Table)	
Port 4:	00-90-27-76-96-93



Unknown Unicast

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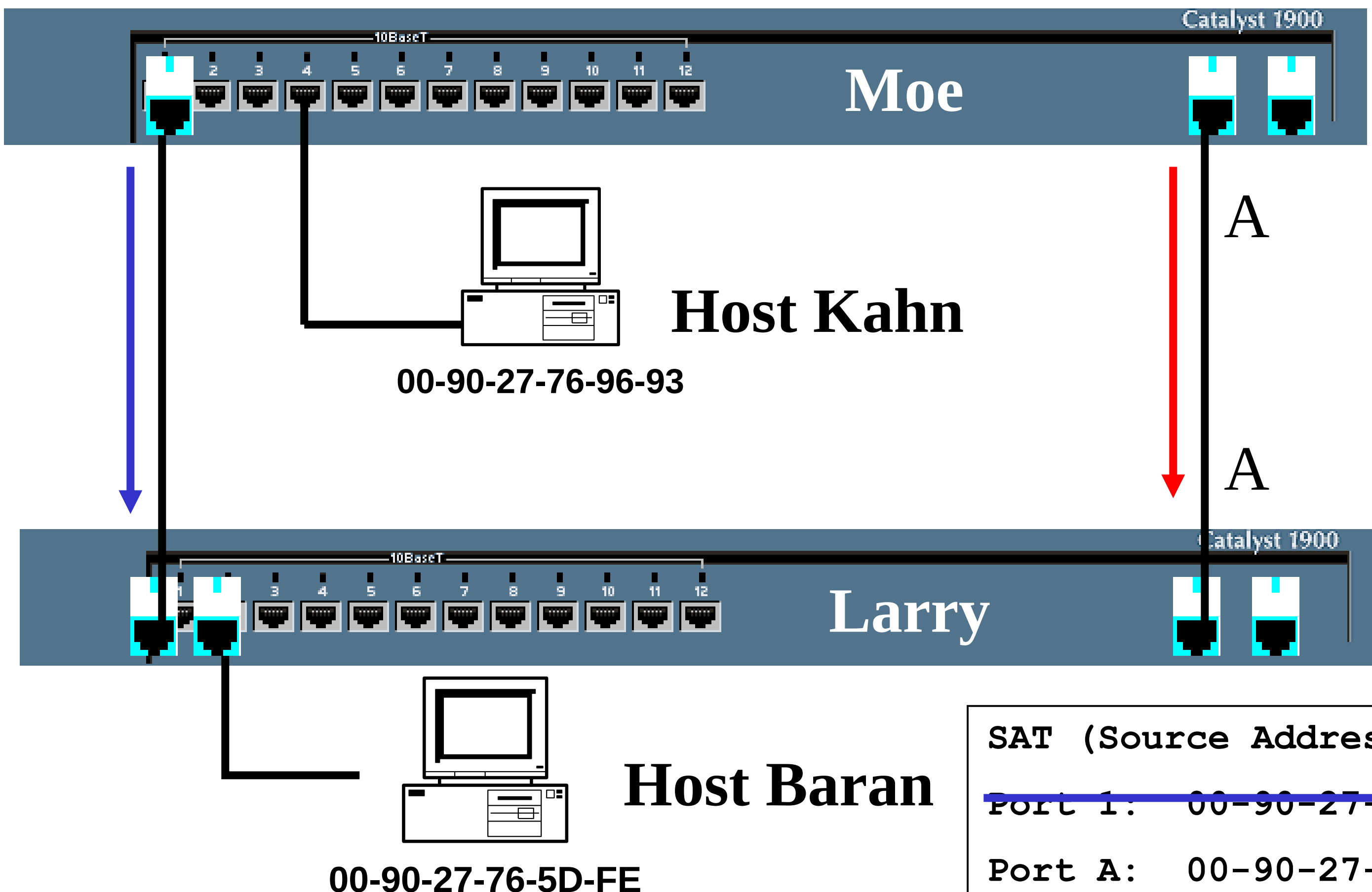
- Switch Larry records the Source MAC of the frame twice with the last one being the most recent.

```
SAT (Source Address Table)

Port 4:   00-90-27-76-96-93
```



SAT (Source Address Table)

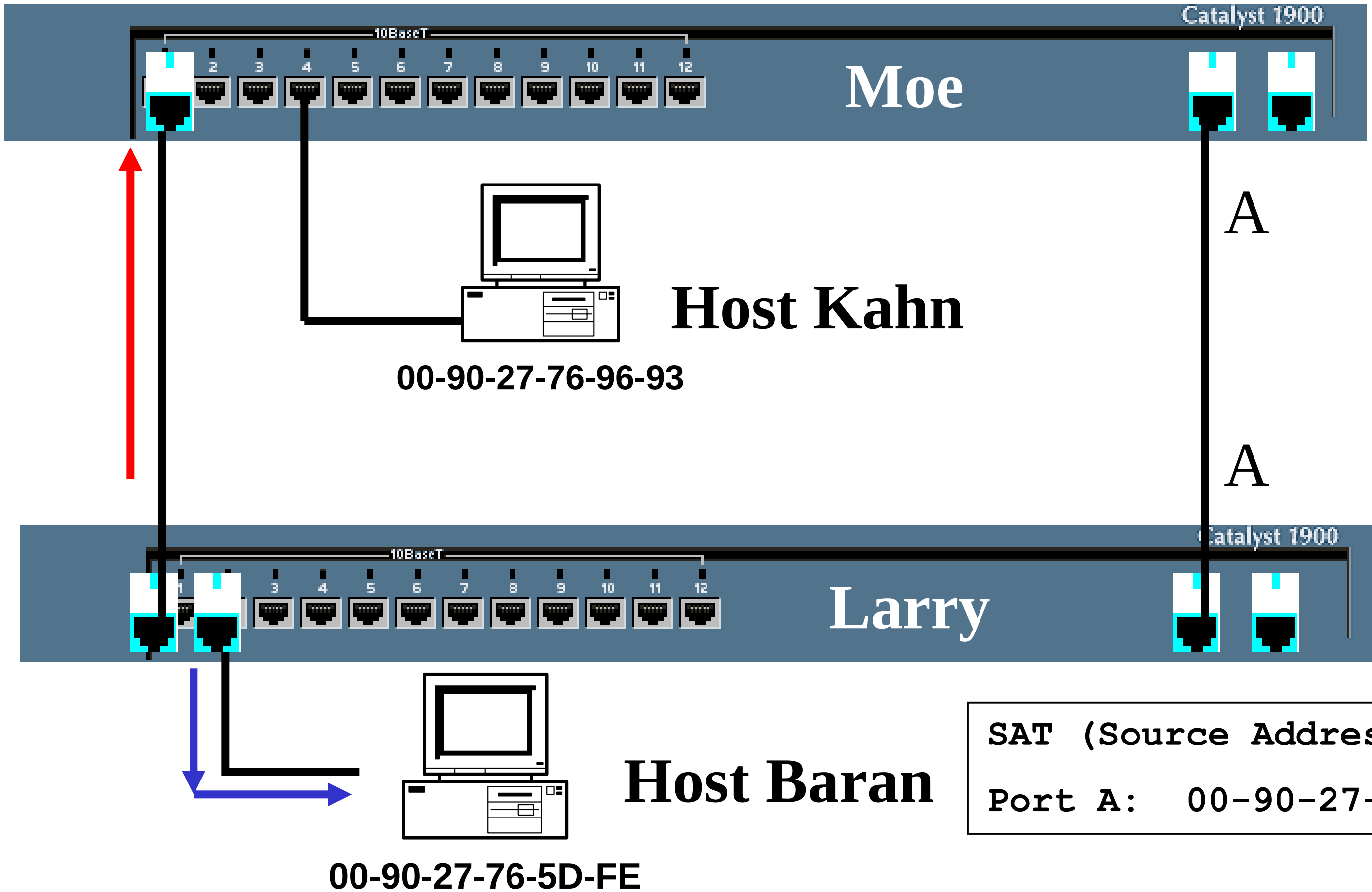
~~Port 1:   00-90-27-76-96-93~~

Port A: 00-90-27-76-96-93

Unknown Unicast

- Switch Larry floods the unknown unicast out all ports, except the incoming port.

SAT (Source Address Table)
Port 1: 00-90-27-76-96-93



SAT (Source Address Table)
Port A: 00-90-27-76-96-93

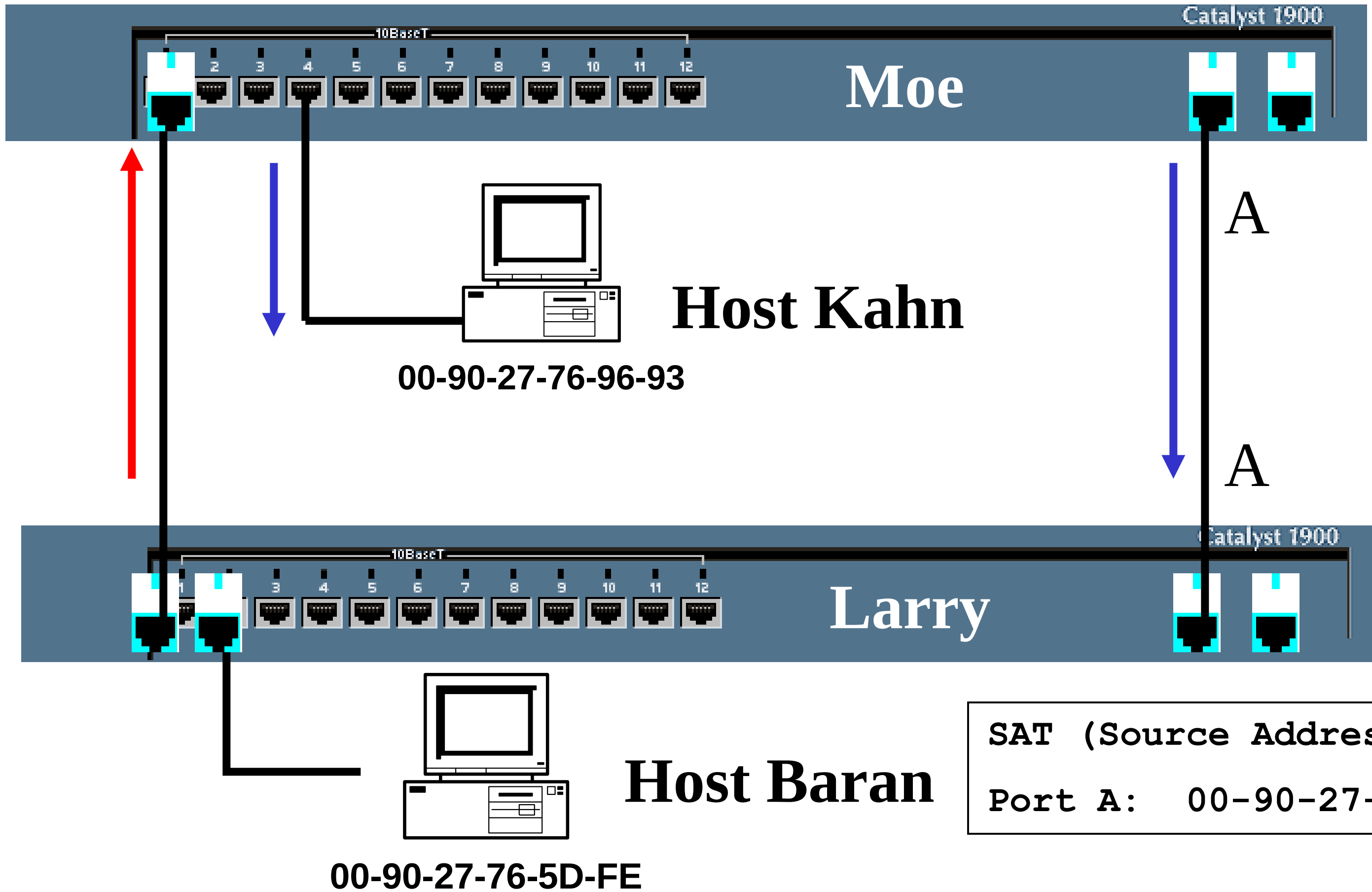
Unknown Unicast

- Switch Moe receives the frame, changes the MAC address table with newer information and floods the unknown unicast out all ports.

SAT (Source Address Table)

~~Port 4: 00-90-27-76-96-93~~

Port 1: 00-90-27-76-96-93



SAT (Source Address Table)

Port A: 00-90-27-76-96-93

Unknown Unicast

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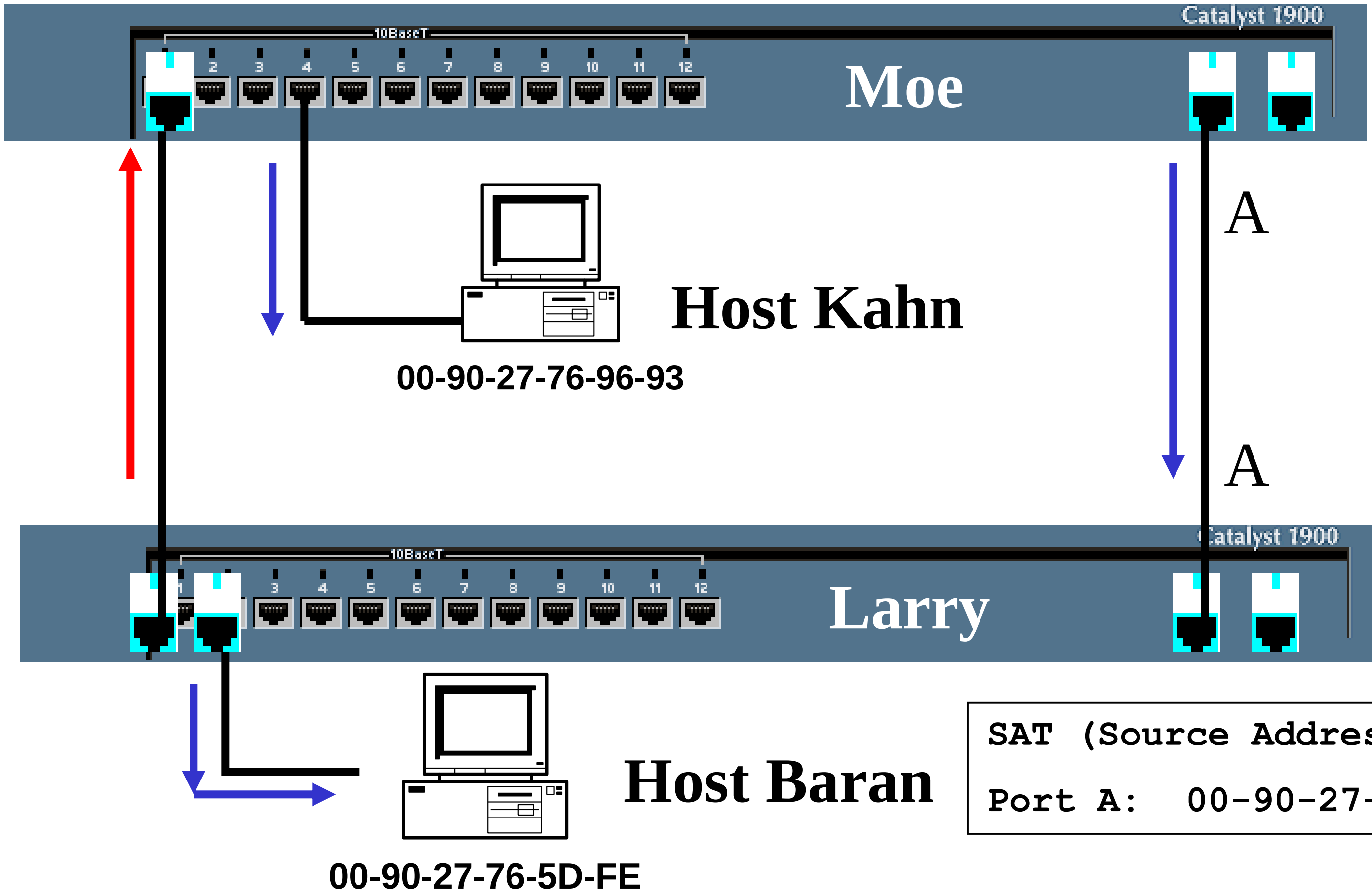
- And the cycle continues!

SAT (Source Address Table)

~~Port 4: 00-90-27-76-96-93~~

Port 1: 00-90-27-76-96-93



SAT (Source Address Table)

Port A: 00-90-27-76-96-93

Layer 2 Broadcast

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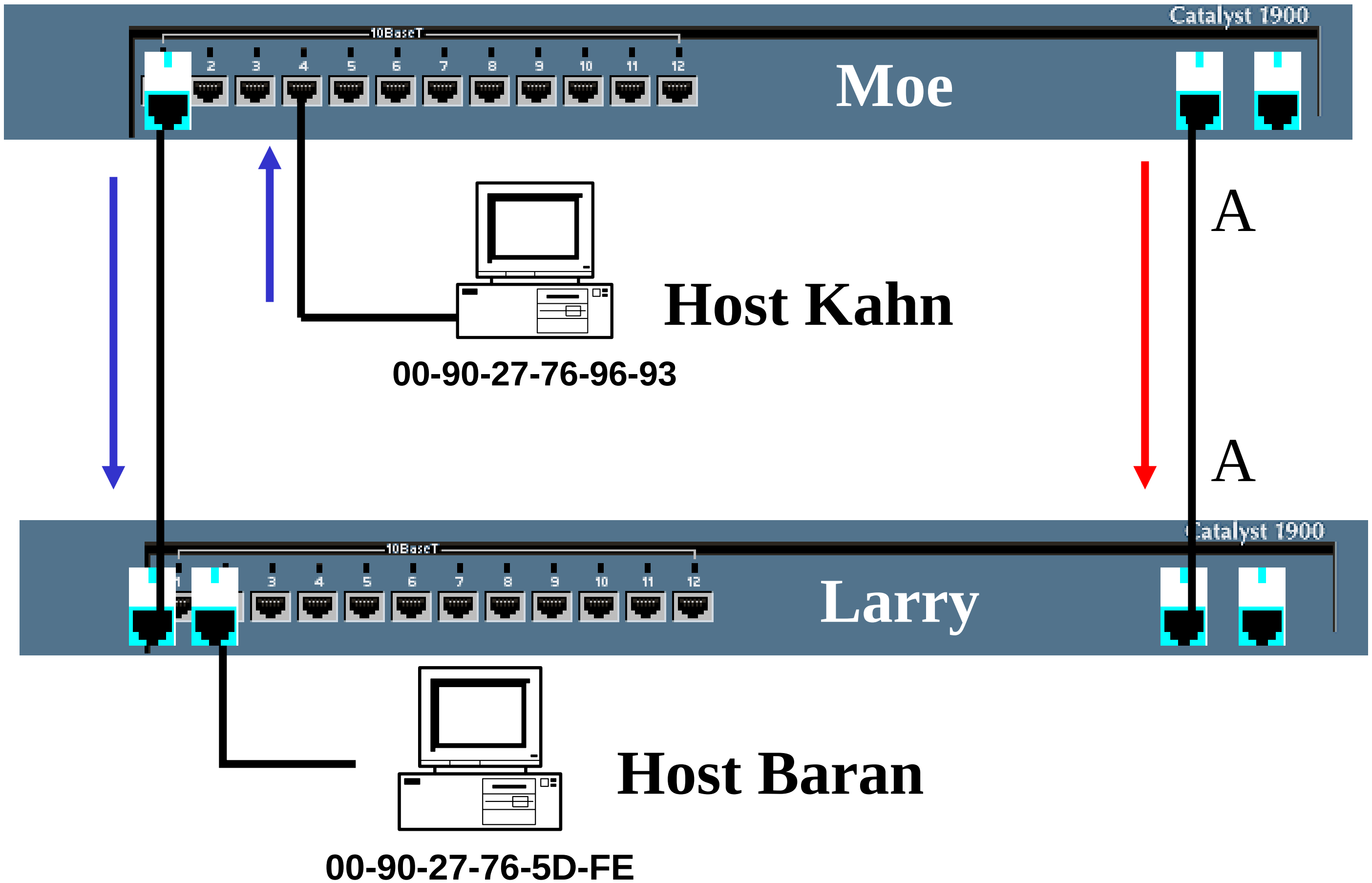
- Host Kahn sends an ARP Request, a Layer 2 broadcast

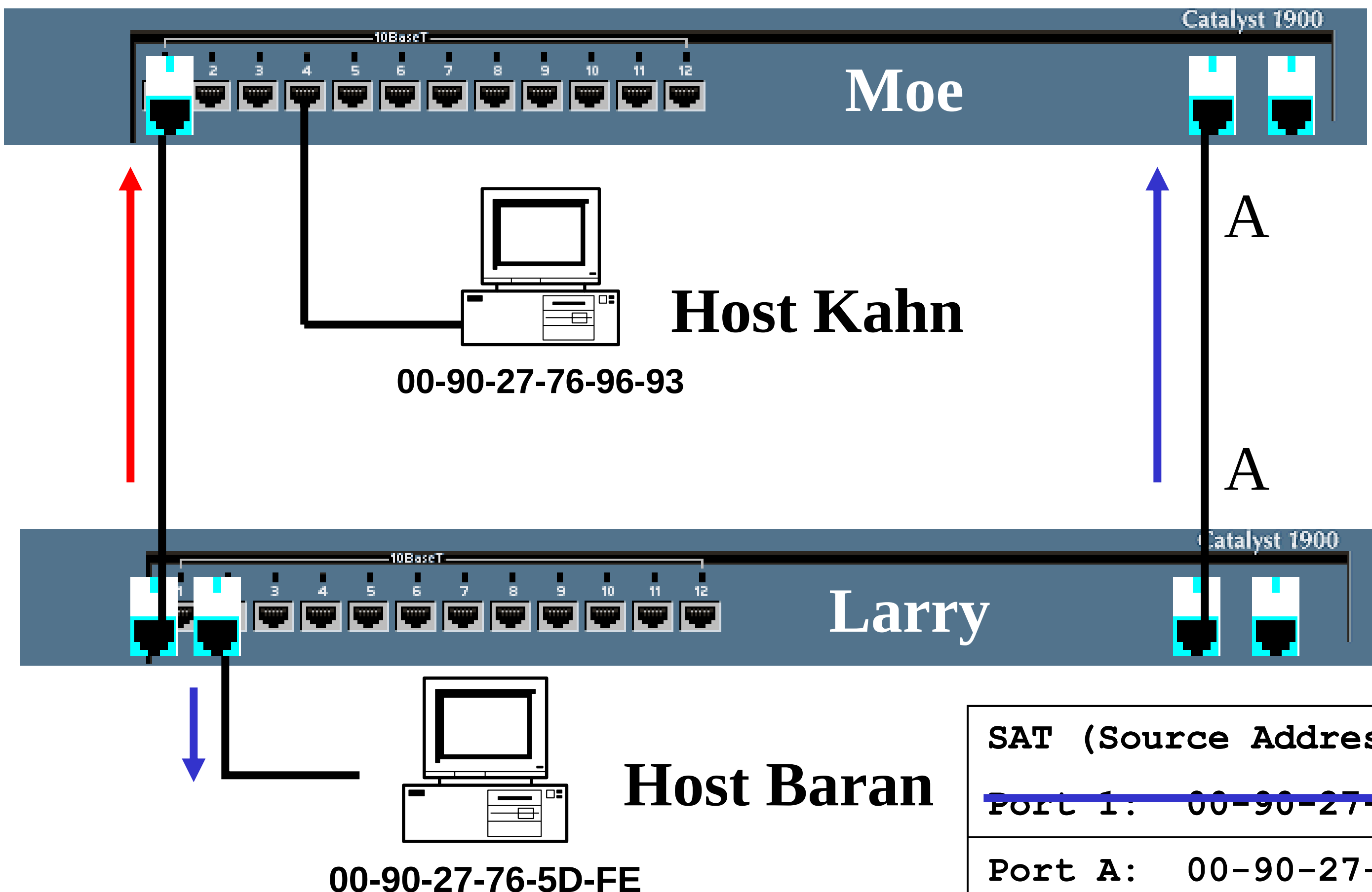
```
SAT (Source Address Table)
Port 1:  00-90-27-76-96-93
```



Layer 2 Broadcast

- Switch Moe floods the frame.
- Switch Larry floods the frames.
- Switches continue to flood duplicate frames.
- Switches constantly modifying MAC Address Tables

SAT (Source Address Table)
Port 1: 00-90-27-76-96-93



SAT (Source Address Table)
~~Port 1: 00-90-27-76-96-93~~
Port A: 00-90-27-76-96-93

STP Prevents Loops

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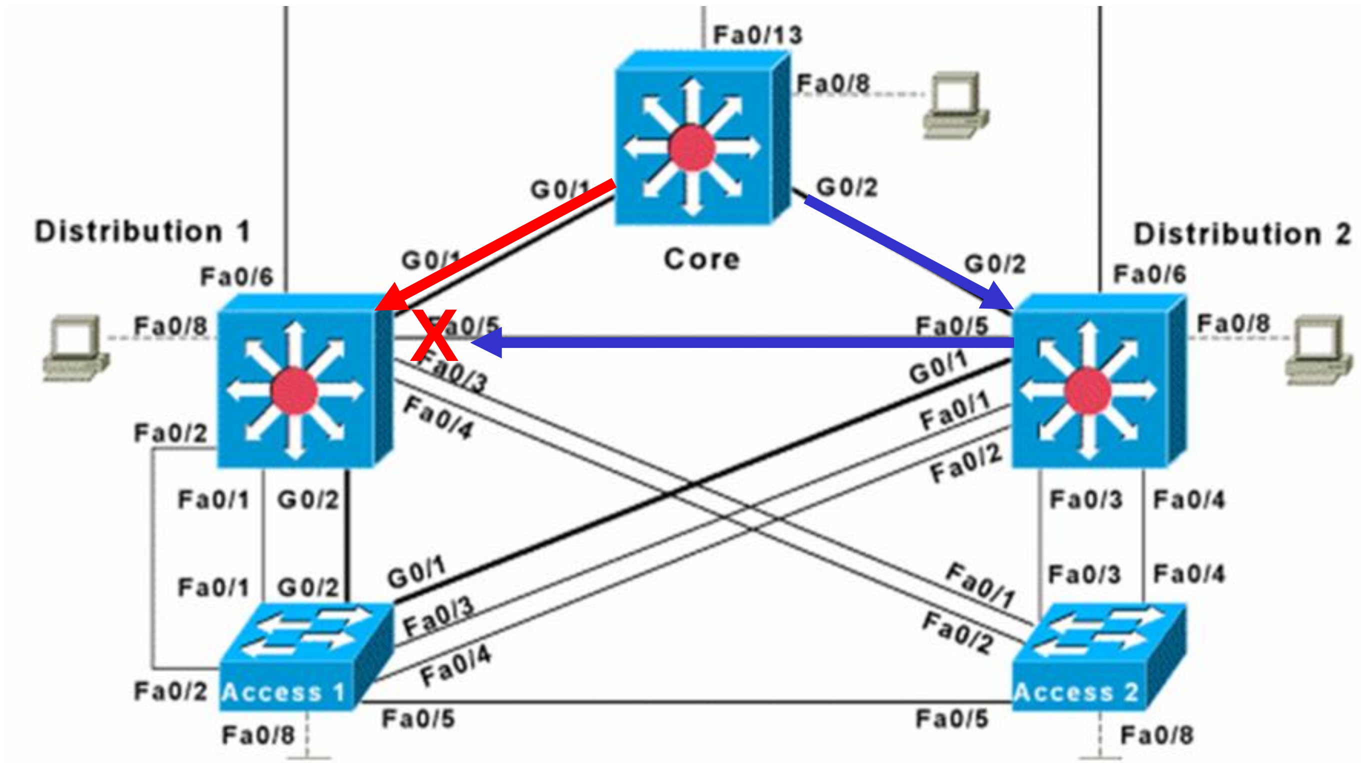
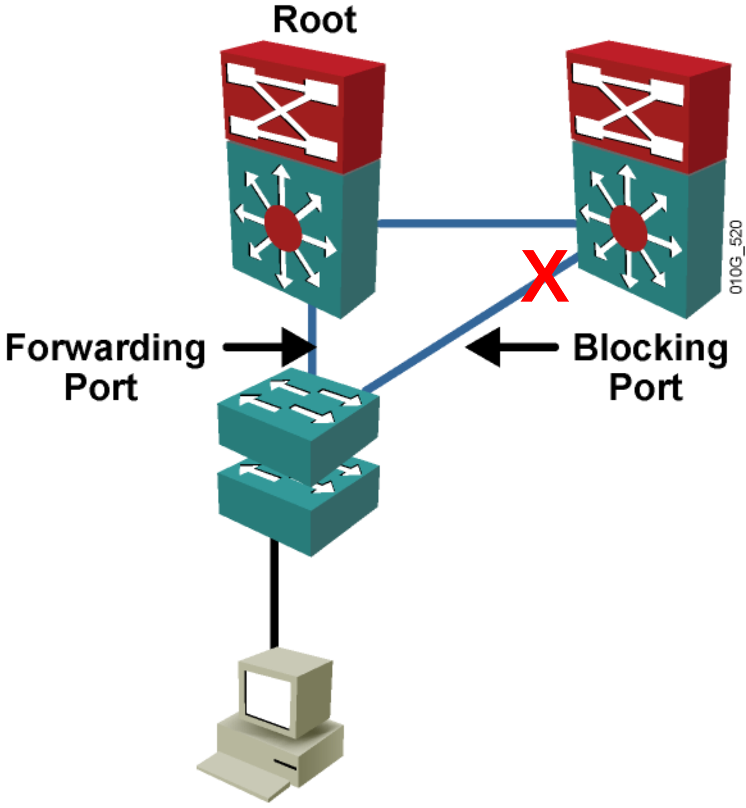
- The purpose of STP is to avoid and eliminate loops in the network by negotiating a loop-free path through a root bridge.
- STP determines where the are loops and blocks links that are redundant.
- Ensures that there will be only one active path to every destination.



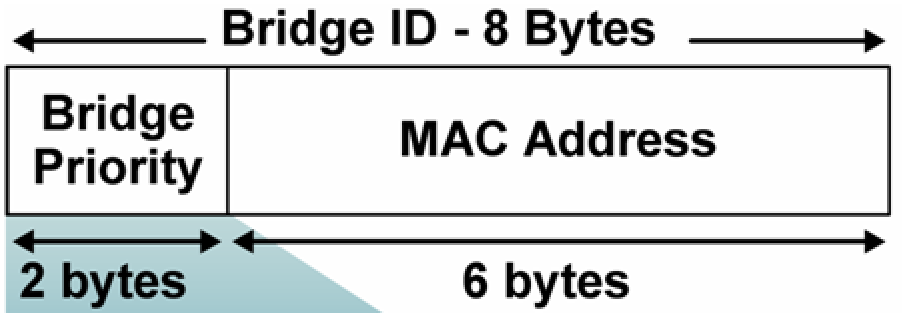
Spanning Tree Algorithm

- STP executes an algorithm called **Spanning Tree Algorithm**.
- STA chooses a reference point, called a root bridge, and then determines the available paths to that reference point.
- If more than two paths exists, STA picks the best path and blocks the rest



Two-key STP Concepts

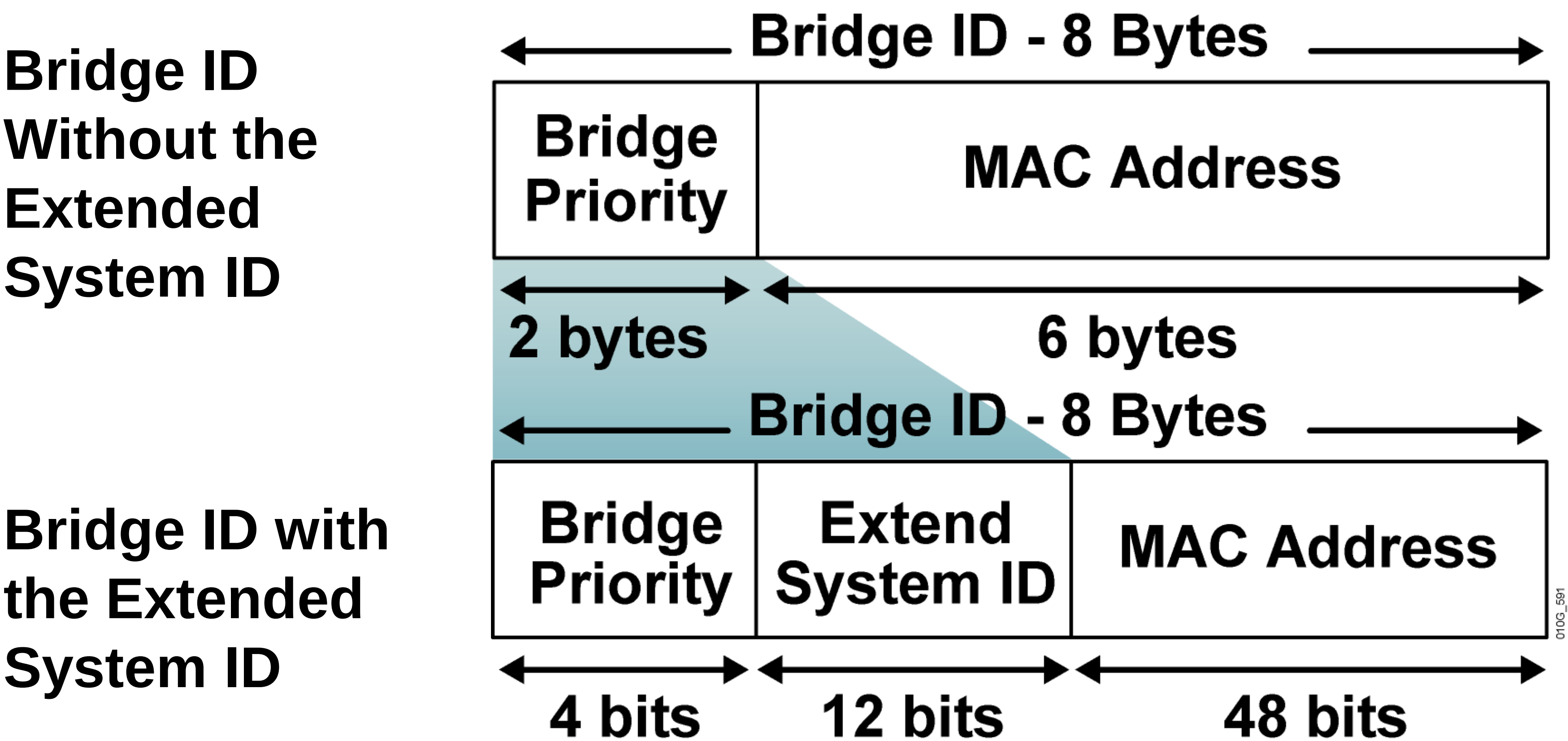
- STP calculations make extensive use of two key concepts in creating a loop-free topology:
  - Bridge ID
  - Path Cost



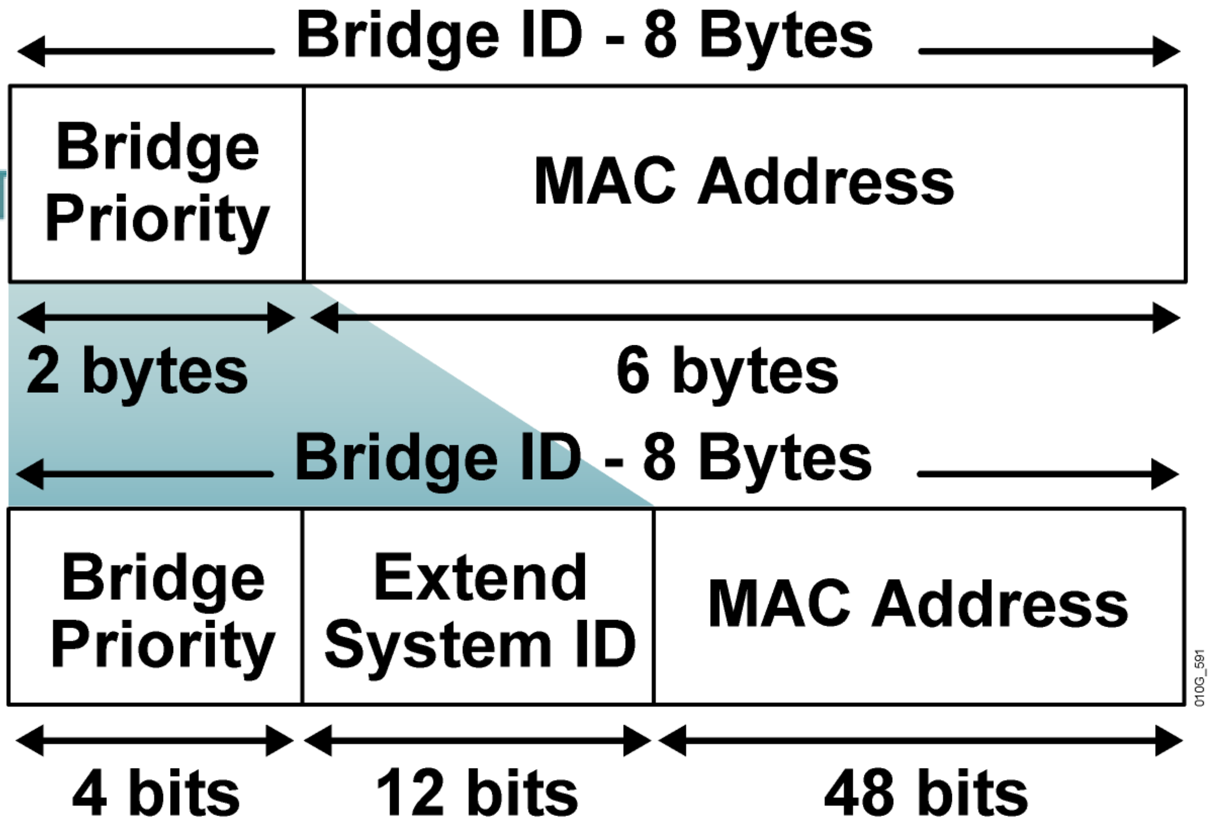
Link Speed	Cost (Revised IEEE Spec)	Cost (Previous IEEE Spec)
10 Gbps	2	1
1 Gbps	4	1
100 Mbps	19	10
10 Mbps	100	100

Bridge ID (BID)

- Bridge ID (BID) is used to identify each bridge/switch.
- The BID is used in determining the center of the network, in respect to STP, known as the root bridge.

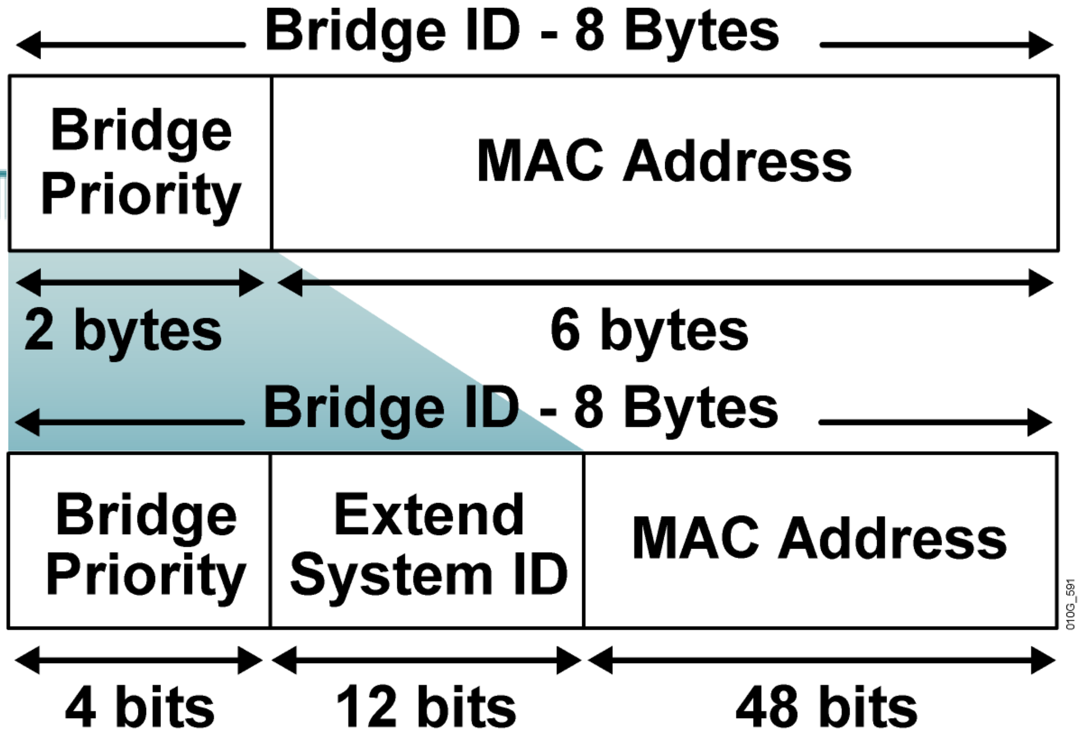


Bridge ID (BID)



- Consists of two components:
  - **A 2-byte Bridge Priority**: Cisco switch defaults to 32,768 or 0x8000.
  - **A 6-byte MAC address**
- **Bridge Priority** is usually expressed in **decimal format** and the **MAC address** in the BID is usually expressed in **hexadecimal format**.

Bridge ID (BID)



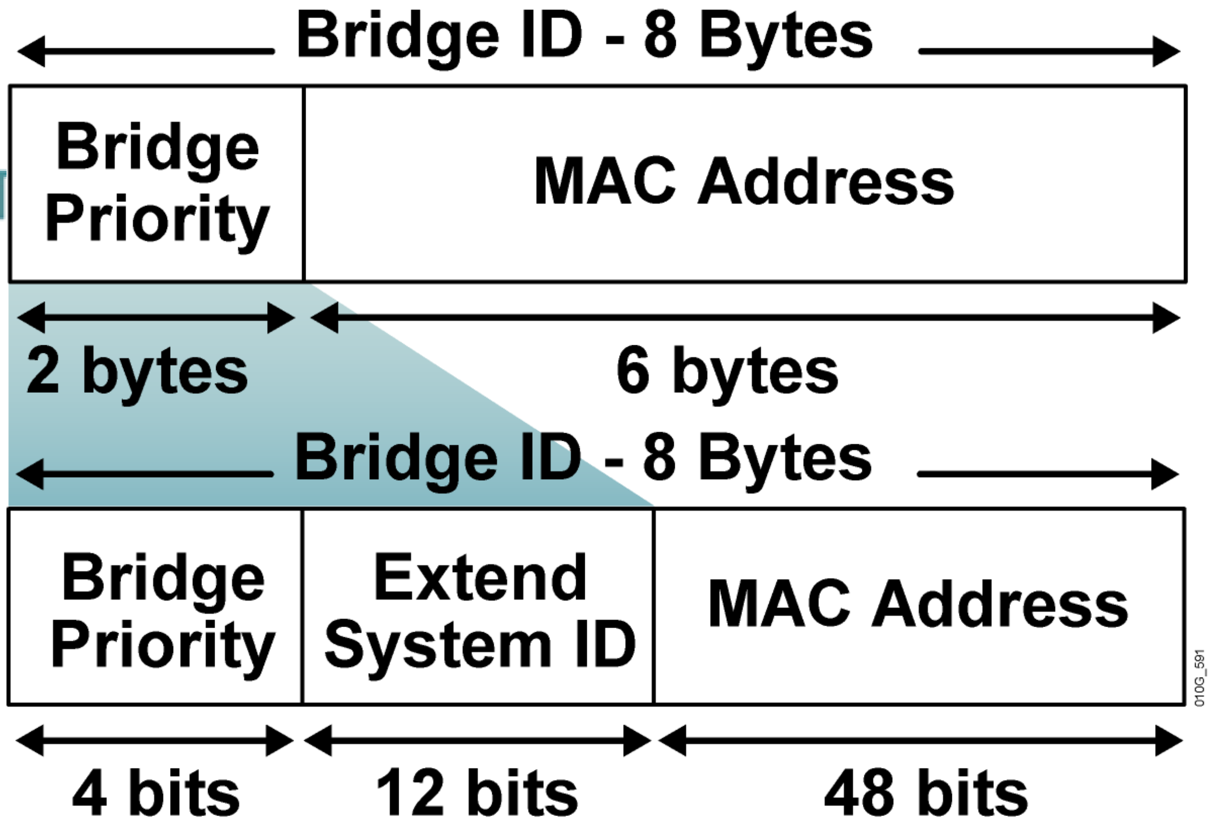
- Spanning tree operation requires that each switch have a unique BID.
- In the **original 802.1D** standard, the BID was composed of the **Priority** Field and the **MAC address** of the switch, and all VLANs were represented by a CST.
- Because **PVST** requires that a separate instance of spanning tree run for each VLAN, the **BID field is required to carry VLAN ID (VID)** information.
- This is accomplished by **reusing a portion of the Priority** field as the extended **system ID to carry a VID**.

Priority = Priority *(Default 32,768)* + VLAN


```
Access2#show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    24577
              Address     000f.2490.1380
              Cost        23
              Port        1 (FastEthernet0/1)
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     0009.7c0b.e7c0
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time 300
<text omitted>

VLAN0010
  Spanning tree enabled protocol ieee
  Root ID     Priority    4106
              Address     000b.fd13.9080
              Cost        19
              Port        1 (FastEthernet0/1)
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID   Priority    32778  (priority 32768 sys-id-ext 10)
              Address     0009.7c0b.e7c0
              Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time 300
```

Bridge ID (BID)



- Used to elect a root bridge (coming)
- **Lowest** Bridge ID is the root.
- If all devices have the same priority, the bridge with the lowest MAC address becomes the root bridge. (Yikes)
- **Note**: For simplicity, in our topologies we will use Bridge Priorities without the Extended System ID.

Path Cost – Original Spec (Linear)

Link Speed	Cost (Revised IEEE Spec)	Cost (Previous IEEE Spec)
10 Gbps	2	1
1 Gbps	4	1
100 Mbps	19	10
10 Mbps	100	100

- Bridges use the concept of cost to evaluate how close they are to other bridges.
- This will be used in the STP development of a loop-free topology .
- Originally, 802.1D defined cost as **1 billion/bandwidth** of the link in Mbps.
  - Cost of 10 Mbps link = 100 or 1000/10
  - Cost of 100 Mbps link = 10 or 1000/100
  - Cost of 1 Gbps link = 1 or 1000/1000
- Running out of room for faster switches including 10 Gbps Ethernet

Path Cost – Revised Spec (Non-Linear)

Link Speed	Cost (Revised IEEE Spec)	Cost (Previous IEEE Spec)
10 Gbps	2	1
1 Gbps	4	1
100 Mbps	19	10
10 Mbps	100	100

- IEEE modified the most to use a non-linear scale with the new values of:
  - 4 Mbps 250 (cost)
  - 10 Mbps 100 (cost)
  - 16 Mbps 62 (cost)
  - 45 Mbps 39 (cost)
  - 100 Mbps 19 (cost)
  - 155 Mbps 14 (cost)
  - 622 Mbps 6 (cost)
  - 1 Gbps 4 (cost)
  - 10 Gbps 2 (cost)

- You can change the path cost by modifying the cost of a port.
- Exercise caution when you do this!
- BID and Path Cost are used to develop a loop-free topology .
- Coming very soon!

Five-Step STP Decision Sequence

- When creating a loop-free topology, STP always uses the same five-step decision sequence:

Five-Step decision Sequence

Step 1 - Lowest BID

Step 2 - Lowest Path Cost to Root Bridge

Step 3 - Lowest Sender BID

Step 4 – Lowest Port Priority

Step 5 - Lowest Port ID

- Bridges use Configuration BPDUs during this four-step process.
- We will assume all BPDUs are configuration BPDUs until otherwise noted.

Five-Step STP Decision Sequence

BPDU key concepts:

- Bridges save a copy of only the best BPDU seen on every port.
- When making this evaluation, it considers all of the BPDUs received on the port, as well as the BPDU that would be sent on that port.
- As every BPDU arrives, it is checked against this five-step sequence to see if it is more attractive (lower in value) than the existing BPDU saved for that port.
- Only the lowest value BPDU is saved.
- Bridges send configuration BPDUs until a more attractive BPDU is received.
- Okay, lets see how this is used...

Elect one Root Bridge

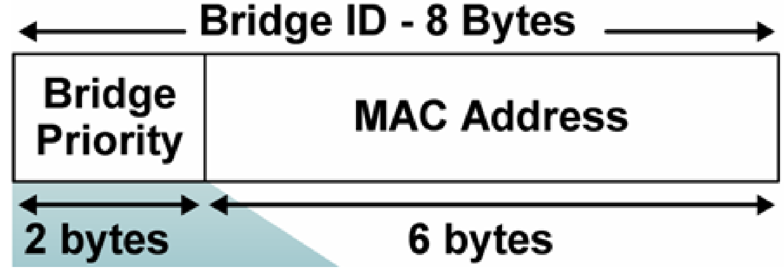
The STP algorithm uses three simple steps to converge on a loop-free topology:

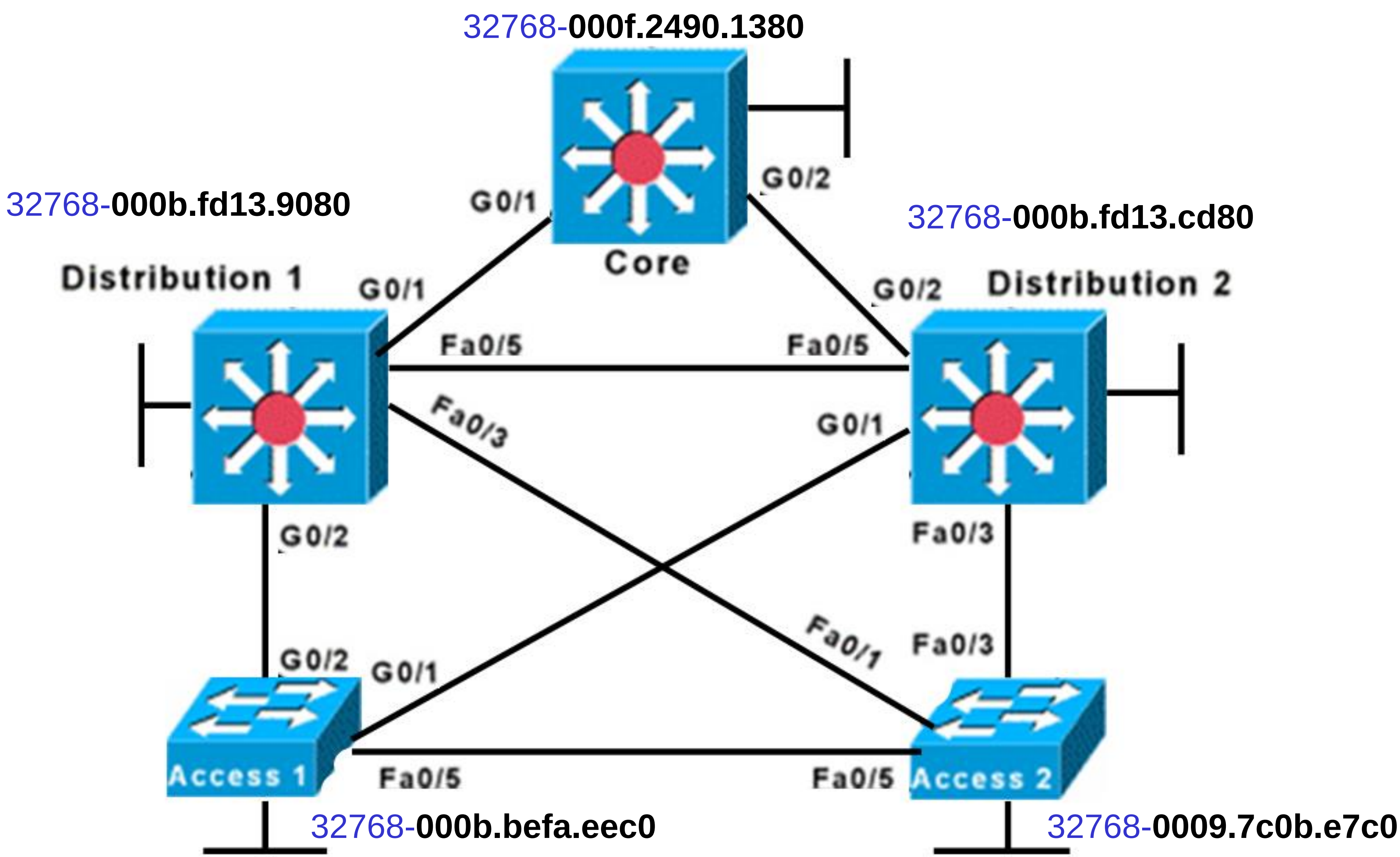
STP Convergence

Step 1 Elect one Root Bridge
Step 2 Elect Root Ports
Step 3 Elect Designated Ports

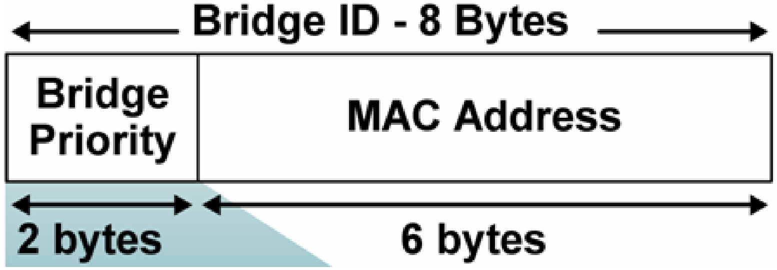
- When the network first starts, all bridges are announcing a chaotic mix of BPDUs.
- All bridges immediately begin applying the five-step sequence decision process.
- Switches need to elect a single Root Bridge.
- Switch with the **lowest BID** wins!
- Note: Many texts refer to the term "highest priority" which is the "lowest" BID value.
- This is known as the **"Root War."**

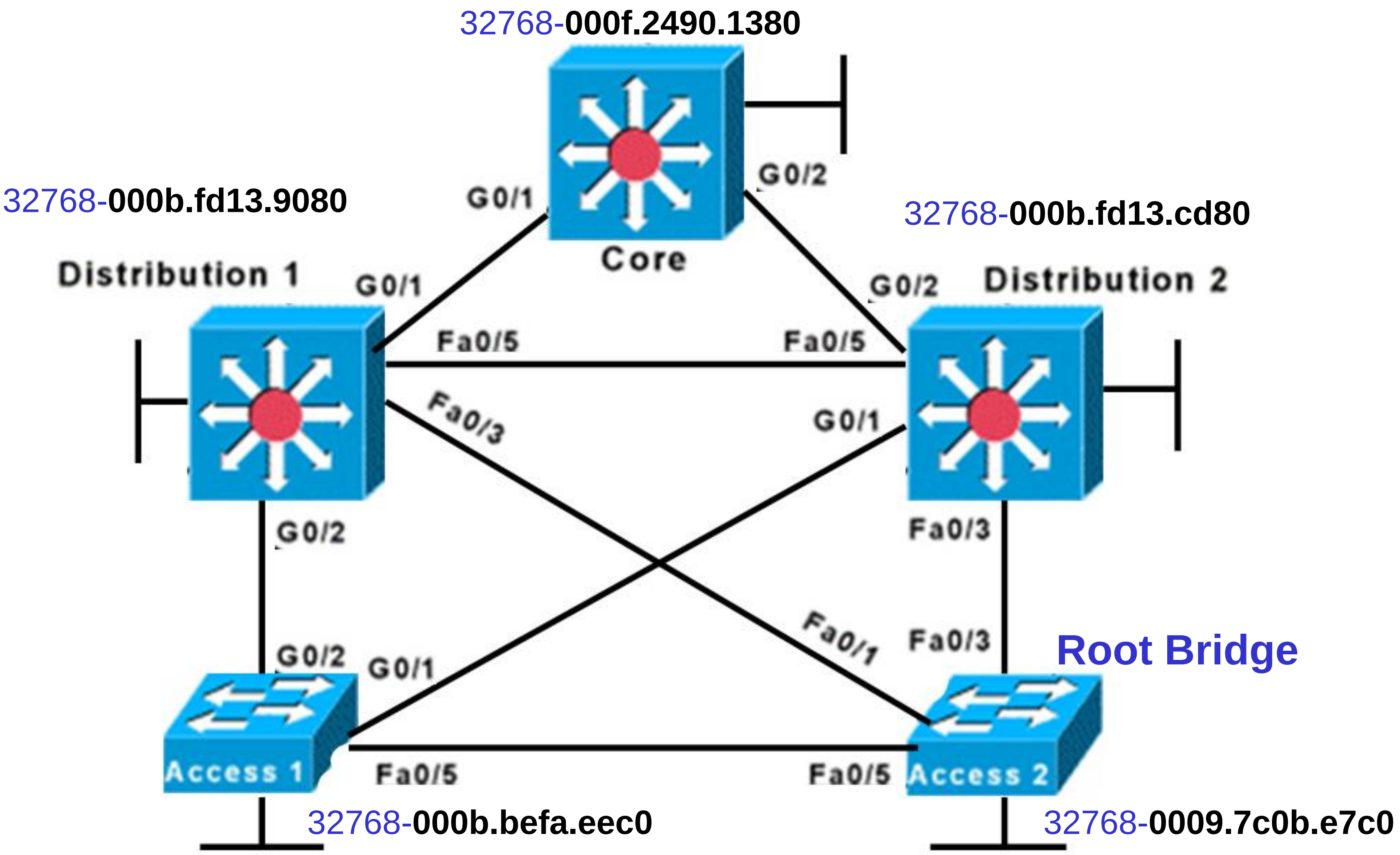
Elect one Root Bridge
Lowest BID wins!





Elect one Root Bridge
Lowest BID wins!





Elect one Root Bridge
Lowest BID wins!

Its all done with BPDUs!
Sent every 2 seconds!

Determines shortest path to Root Bridge
Determines which ports will forward frames.

Bytes	Field
2	Protocol ID
1	Version
1	Message type
1	Flags
8	Root ID
4	Cost of path
8	Bridge ID
2	Port ID
2	Message age
2	Max age
2	Hello time
2	Forward delay

310P_126

Who is the root bridge?

How far away is the root bridge?

What is the BID of the bridge that sent this BPDU?

What port on the sending bridge did this BPDU come from?

Elect one Root Bridge
Lowest BID wins!


```
BPDU
802.3 Header
  Destination:   01:80:C2:00:00:00  Mcast 802.1d Bridge group
  Source:        00:D0:C0:F5:18:D1
  LLC Length:    38
802.2 Logical Link Control (LLC) Header
  Dest. SAP:     0x42  802.1 Bridge Spanning Tree
  Source SAP:    0x42  802.1 Bridge Spanning Tree
  Command:       0x03  Unnumbered Information
802.1 - Bridge Spanning Tree
  Protocol Identifier:   0
  Protocol Version ID:   0
  Message Type:          0  Configuration Message
  Flags:                 %00000000
  Root Priority/ID:      0x8000/ 00:D0:C0:F5:18:C0
  Cost Of Path To Root:  0x00000000  (0)
  Bridge Priority/ID:    0x8000/ 00:D0:C0:F5:18:C0
  Port Priority/ID:      0x80/ 0x1D
  Message Age:           0/256 seconds (exactly 0  seconds)
  Maximum Age:           5120/256 seconds (exactly 20  seconds)
  Hello Time:            512/256 seconds (exactly 2  seconds)
  Forward Delay:         3840/256 seconds (exactly 15  seconds)
```

Root Bridge Selection Criteria

- At the beginning, all bridges assume they are the center of the universe and declare themselves as the Root Bridge, by placing its own BID in the Root BID field of the BPDU.

Bytes	Field
2	Protocol ID
1	Version
1	Message Type
1	Flags
8	Root ID
4	Cost of Path
8	Bridge ID
2	Port ID
2	Message Age
2	Maximum Age Time
2	Hello Time
2	Forward Delay

310P_127

When first booted, root ID = bridge ID.

Elect one Root Bridge
Lowest BID wins!

Bytes	Field
2	Protocol ID
1	Version
1	Message type
1	Flags
8	Root ID
4	Cost of path
8	Bridge ID
2	Port ID
2	Message age
2	Max age
2	Hello time
2	Forward delay

310P_126

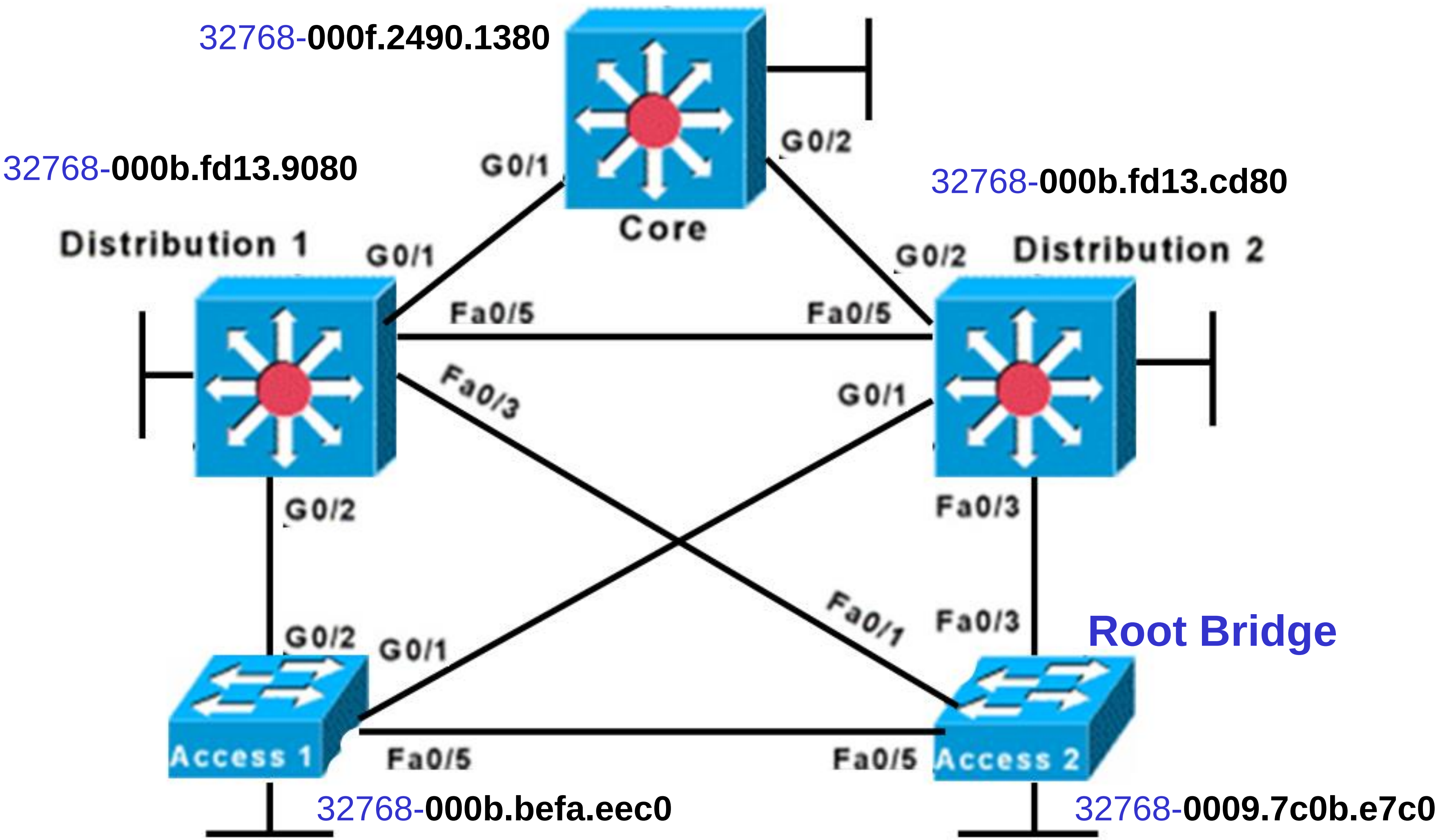
Who is the root bridge?

How far away is the root bridge?

What is the BID of the bridge that sent this BPDU?

What port on the sending bridge did this BPDU come from?

- Once all of the switches see that Access2 has the lowest BID, they are all in agreement that Access2 is the Root Bridge.



Rigging the Root Bridge Election

- The switch with the lowest BID becomes the root.
- The root switch can be determined by lowering the priority on that switch, below the default of 32768.
- There are two ways to lower the priority on Switch-2 to make it the Root Bridge

```
Switch-2(config)#spanning-tree vlan 1 root primary
  or
Switch-2(config)#spanning-tree vlan 1 priority 4096
```

- The **spanning-tree vlan 1 priority 4096** command lowers the priority from 32768 to 4096, thus making it the root switch.
- The **spanning-tree vlan 1 root primary** command lowers the priority to 24576 (on a 2950 switch), thus making it the root switch.

Elect Root Ports

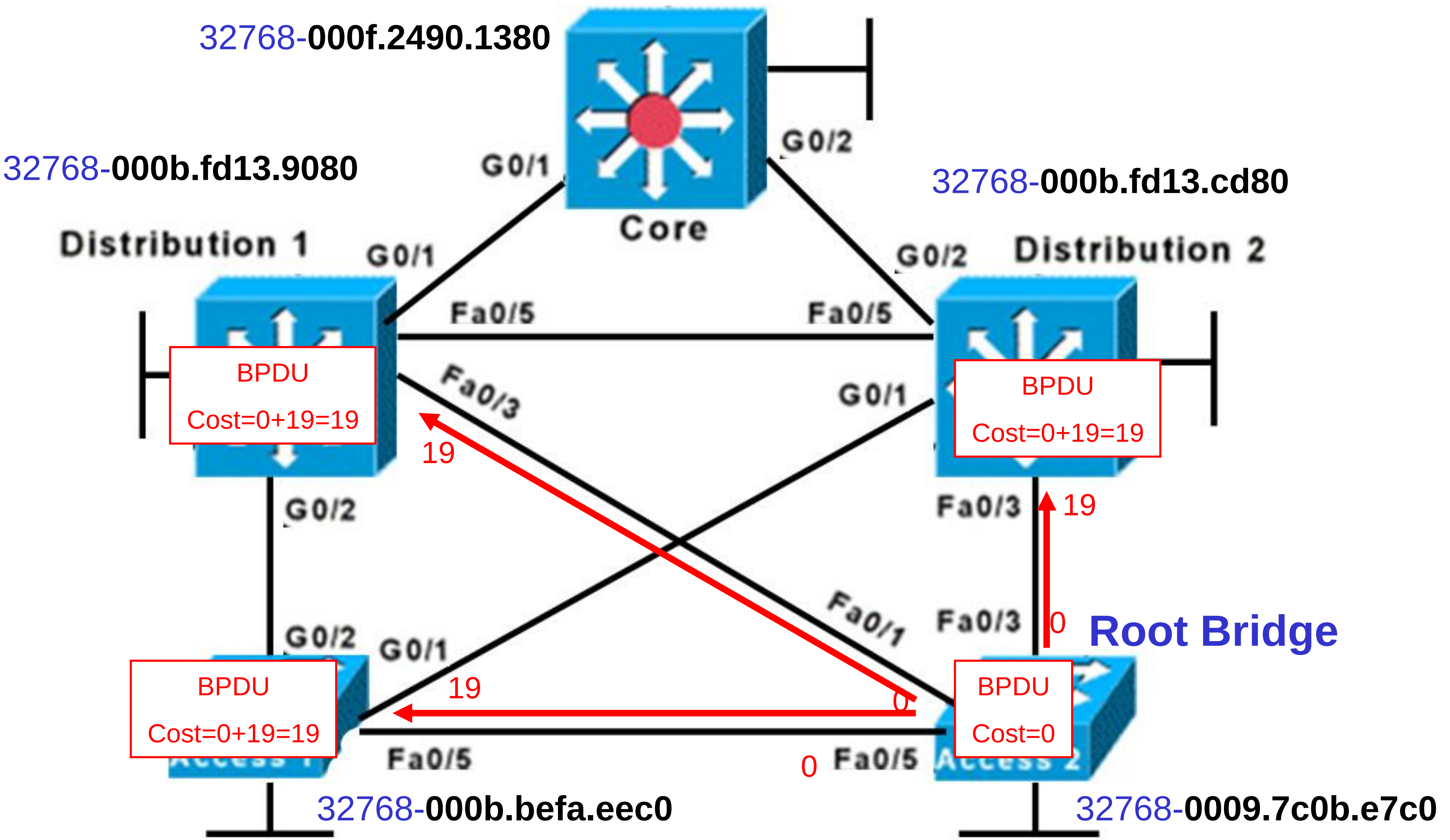
STP Convergence

Step 1 Elect one Root Bridge
Step 2 Elect Root Ports
Step 3 Elect Designated Ports

Link Speed	Cost (Revised IEEE Spec)
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100

- Now that the Root War has been won, switches move on to selecting **Root Ports**.
- A bridge's **Root Port** is the port closest to the Root Bridge.
- Bridges use the **cost** to determine closeness.
- **Every non-Root Bridge will select one Root Port!**
- Specifically, bridges track the **Root Path Cost**, the cumulative cost of all links to the Root Bridge.

- Root Bridge, Access2 sends out BPDUs, containing a Root Path Cost of 0.
- Access1, Distribution1, and Distribution2 receives these BPDUs and adds the Path Cost of the FastEthernet interface to the Root Path Cost contained in the BPDU.
- Access1, Distribution1, and Distribution2 add Root Path Cost 0 PLUS its Port cost of 19 = 19.
- This value is used internally and used in BPDUs to other switches..



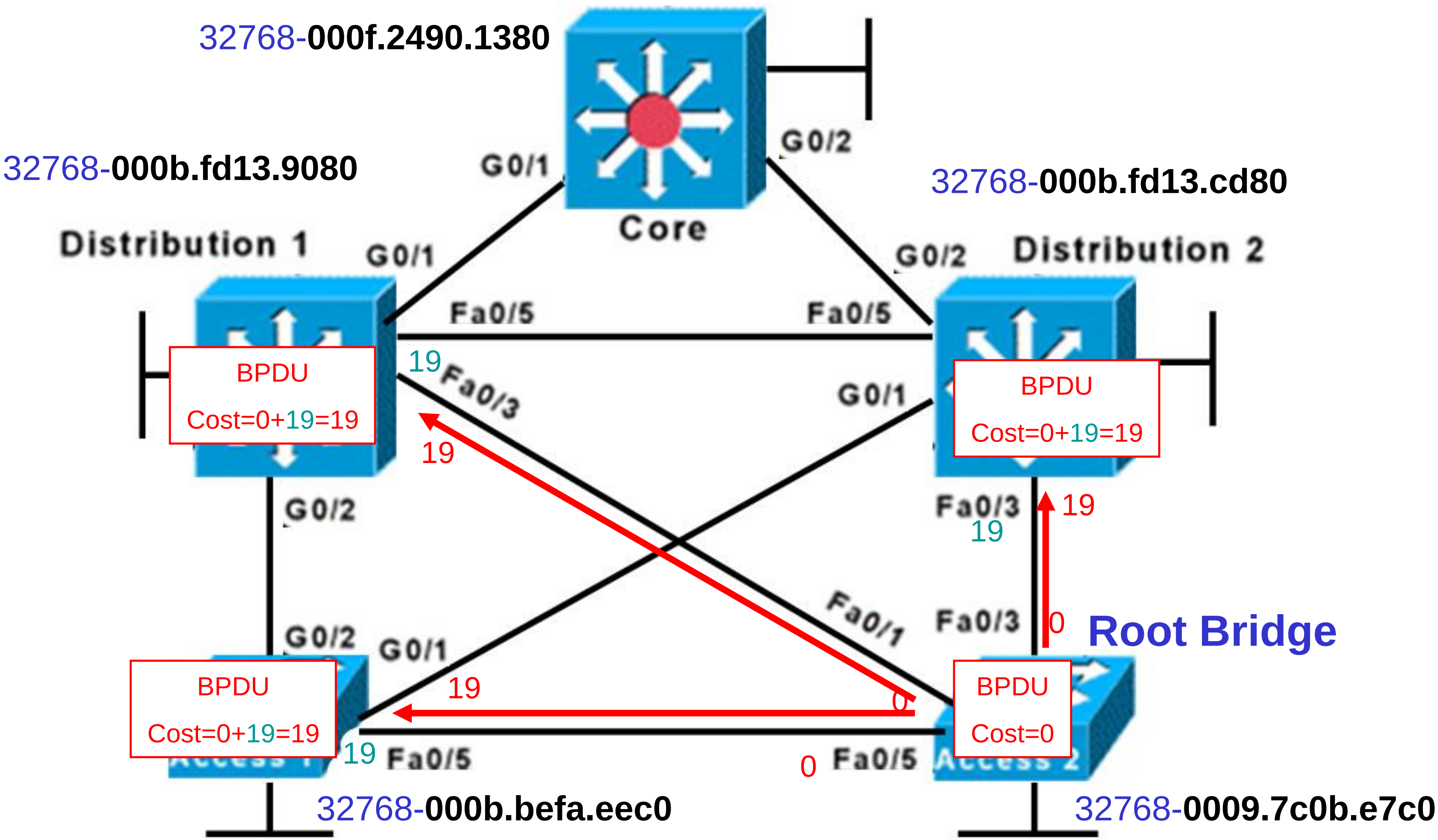
Difference b/t Path Cost and Root Path Cost

Path Cost:

- The value assigned to each port.
- Added to BPDUs received on that port to calculate Root Path Cost.

Root Path Cost

- Cumulative cost to the Root Bridge.
- This is the value transmitted in the BPDU.
- Calculated by adding the receiving port's Path Cost to the valued contained in the BPDU.



show spanning-tree

Link Speed	Cost (Revised IEEE Spec)
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100

```
Distribution1#show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority     32769
              Address      0009.7c0b.e7c0
              Cost         19
              Port         3 (FastEthernet0/3)
              Hello Time    2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID   Priority     32769  (priority 32768 sys-id-ext 1)
              Address      000b.fd13.9080
              Hello Time    2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time 300
Interface        Port ID                    Designated                Port ID
Name             Prio.Nbr      Cost Sts      Cost Bridge ID            Prio.Nbr
---------------- -------- --------- --- --------- -------------------- --------
Fa0/1            128.1           19 BLK        19 32769 000b.befa.eec0 128.1
Fa0/2            128.2           19 BLK        19 32769 000b.befa.eec0 128.2
Fa0/3            128.3           19 FWD         0 32769 0009.7c0b.e7c0 128.1
Fa0/4            128.4           19 BLK         0 32769 0009.7c0b.e7c0 128.2
Fa0/5            128.5           19 FWD        19 32769 000b.fd13.9080 128.5
Gi0/1            128.25           4 FWD        19 32769 000b.fd13.9080 128.25
Interface        Port ID                    Designated                Port ID
Name             Prio.Nbr      Cost Sts      Cost Bridge ID            Prio.Nbr
---------------- -------- --------- --- --------- -------------------- --------
Gi0/2            128.26           4 BLK        19 32769 000b.befa.eec0 128.26
```

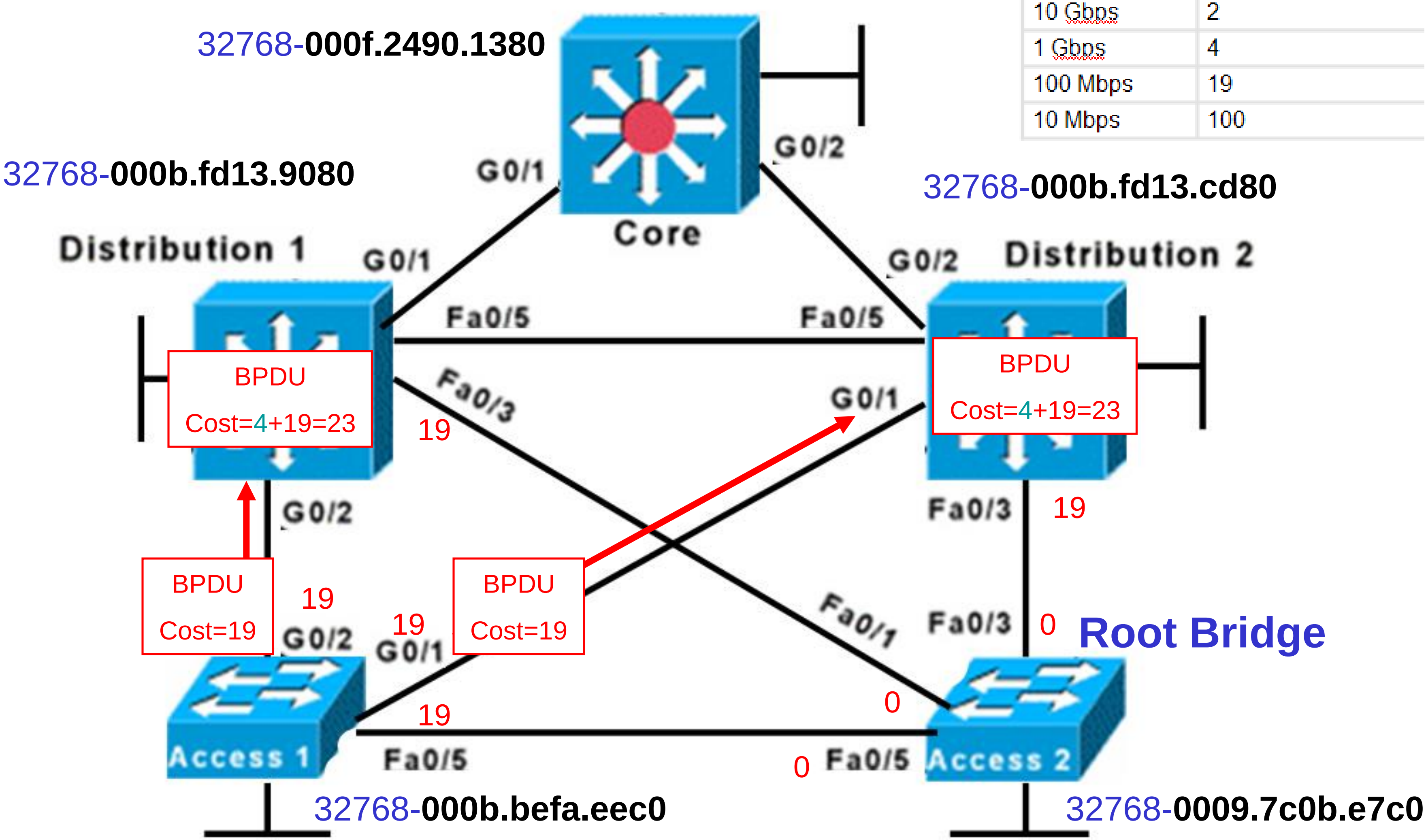
show spanning-tree detail

Link Speed	Cost (Revised IEEE Spec)
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100

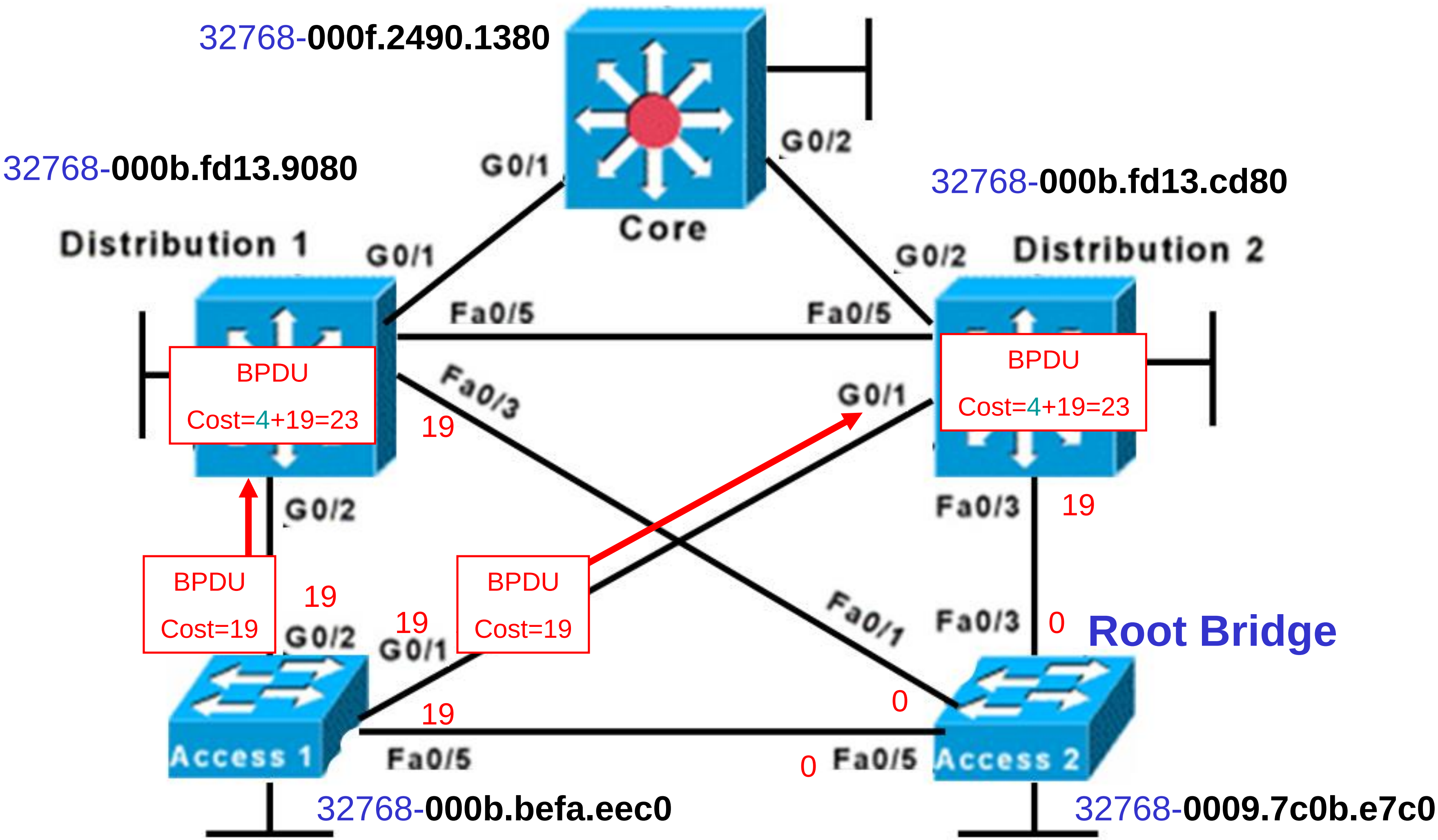
```
Distribution1#show spanning-tree detail
 VLAN0001 is executing the ieee compatible Spanning Tree protocol
  Bridge Identifier has priority 32768, sysid 1, address 000b.fd13.9080
  Configured hello time 2, max age 20, forward delay 15
  Current root has priority 32769, address 0009.7c0b.e7c0
  Root port is 3 (FastEthernet0/3), cost of root path is 19
  Topology change flag not set, detected flag not set
  Number of topology changes 7 last change occurred 00:14:34 ago
          from GigabitEthernet0/1
  Times:  hold 1, topology change 35, notification 2
          hello 2, max age 20, forward delay 15
  Timers: hello 0, topology change 0, notification 0, aging 300
```

- Switches now send BPDUs with their Root Path Cost out other interfaces.
- **Note**: STP costs are incremented as BPDUs are received on a port, not as they are sent out a port.
- Access 1 uses this value of 19 internally and sends BPDUs with a Root Path Cost of 19 out all other ports.

Link Speed	Cost (Revised IEEE Spec)
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100

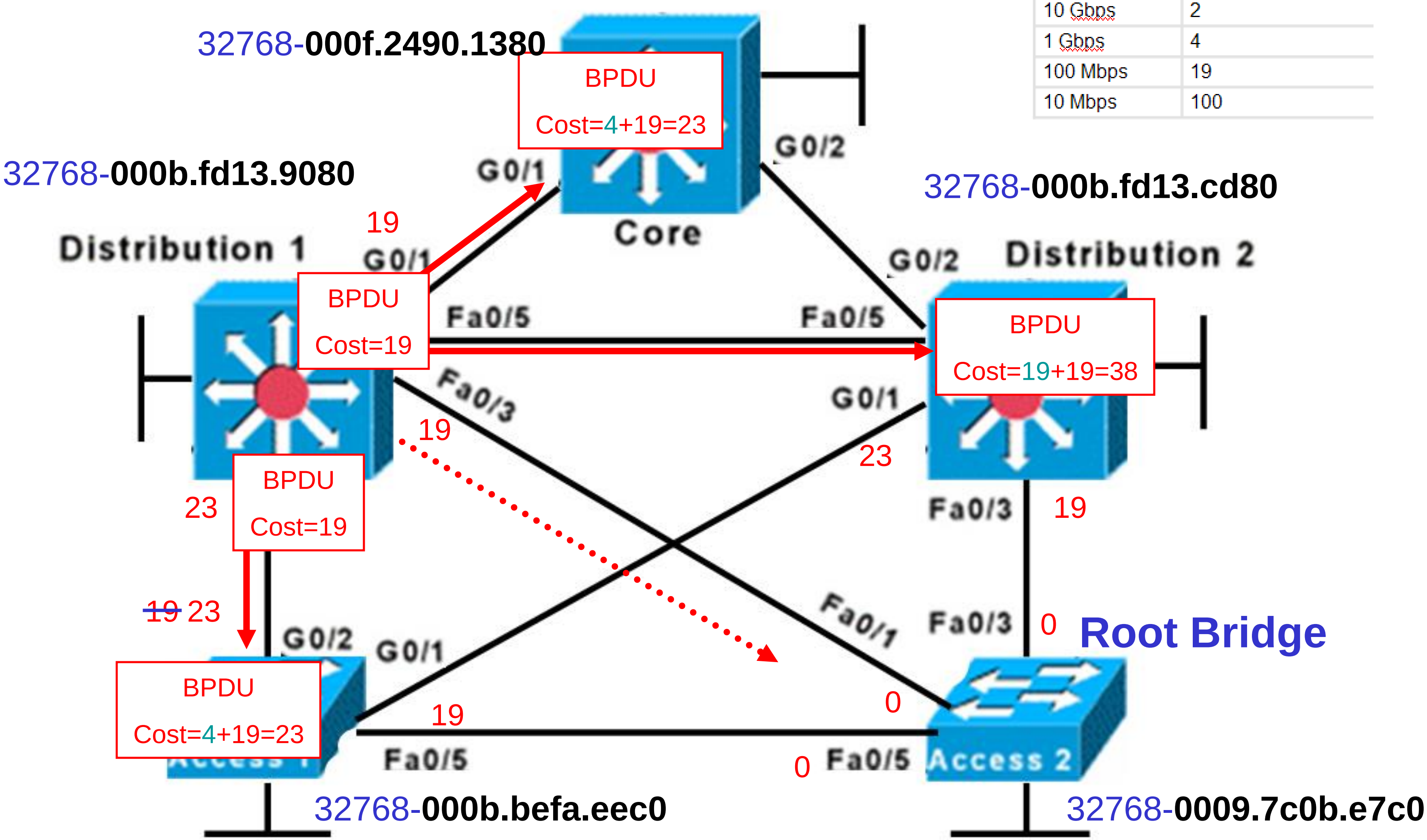


- Distribution 1 and Distribution 2 receive the BPDUs from Access 1, and adds the Path Cost of 4 to those interfaces, giving a Root Path Cost of 23.
- However, both of these switches already have an “internal” Root Path Cost of 19 that was received on another interface.
- Distribution 1 and Distribution 2 use the better BPDU of 19 when sending out their BPDUs to other switches.



- Distribution 1 now sends BPDUs with its Root Path Cost out other interfaces.
- Again, STP costs are incremented as BPDUs are received on a port, not as they are sent out a port.

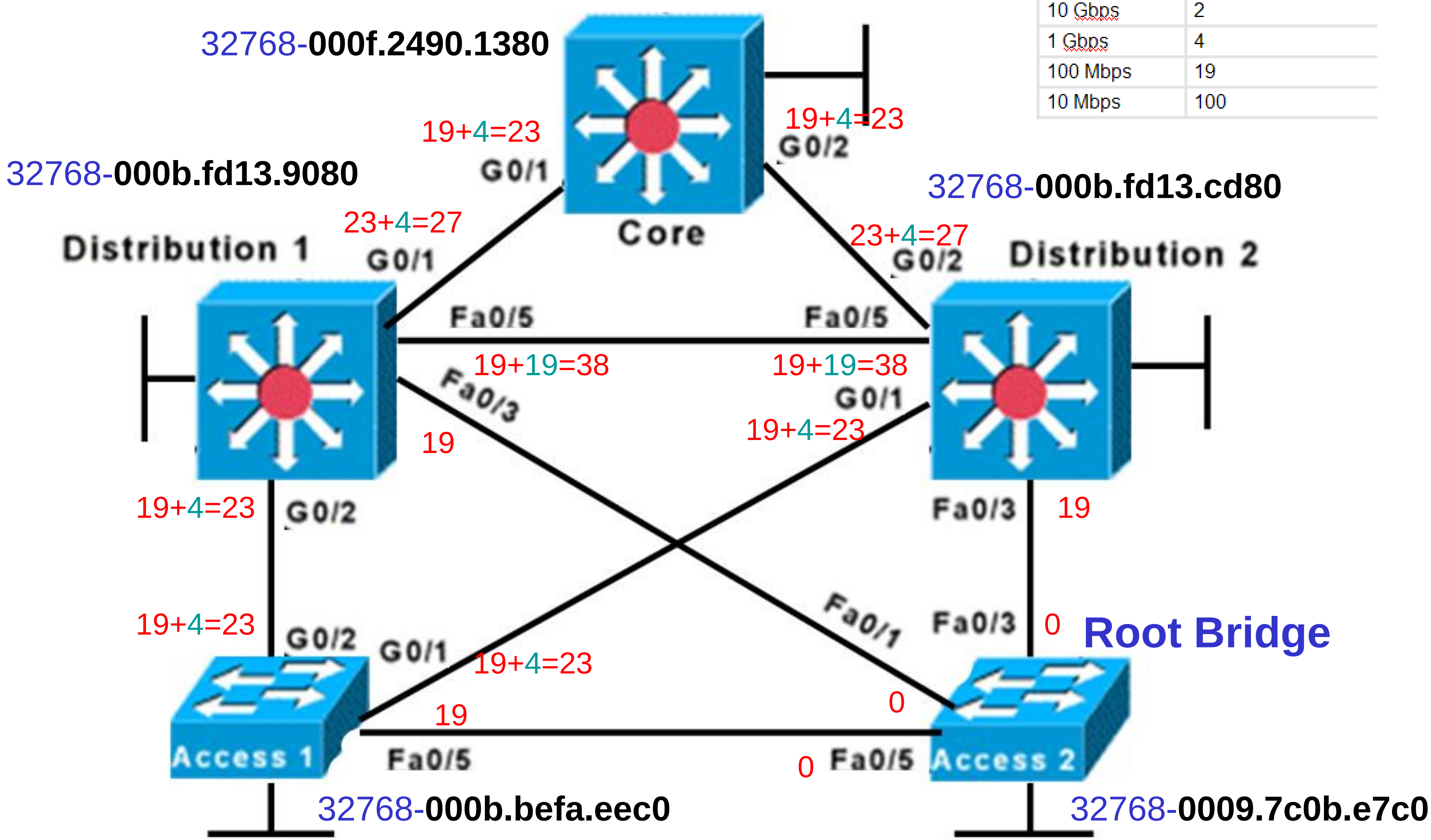
Link Speed	Cost (Revised IEEE Spec)
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100



Final Results

- Ports show ***Received*** Root Path Cost = BPDU Root Path Cost + Path Cost of Interface, after the "best" BPDU is received on that port from the neighboring switch.
- This is the cost of reaching the Root Bridge from this interface towards the neighboring switch.
- ***Now let's see how this is used!***

Link Speed	Cost (Revised IEEE Spec)
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100



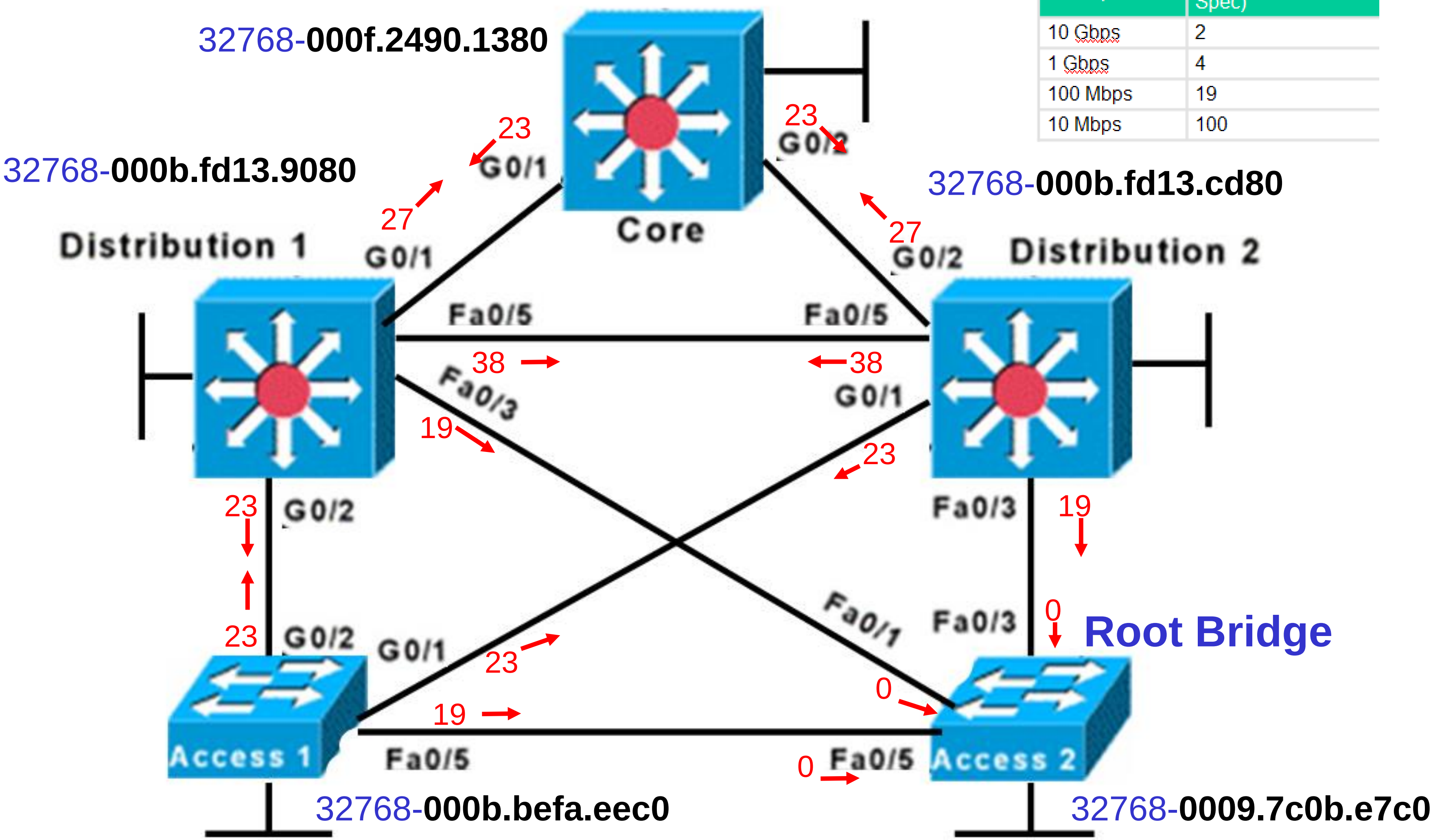
Next:

- Elect Root Ports
- Elect Designated Ports
- Non-Designated Ports: All other ports

Elect Root Ports

- Every non-Root bridge must select one **Root Port**.
- A bridge's **Root Port** is the port closest to the Root Bridge.
- Bridges use the **cost** to determine closeness.

Link Speed	Cost (Revised IEEE Spec)
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100

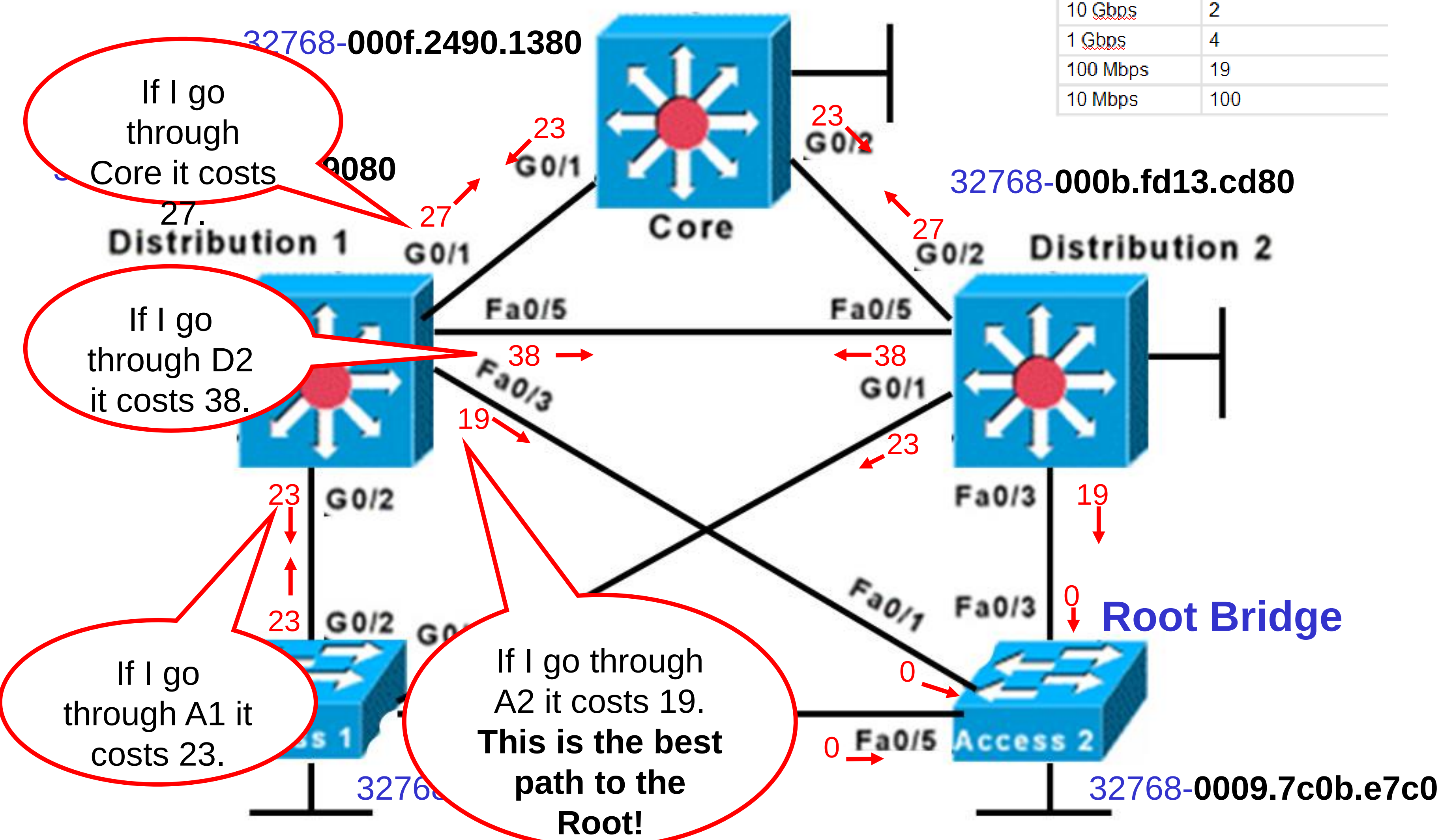


Elect Root Ports: (Review)

- Ports show ***Received*** Root Path Cost = BPDU Root Path Cost + Path Cost of Interface, after the “best” BPDU is received on that port from the neighboring switch.
- This is the cost of reaching the Root Bridge from this interface towards the neighboring switch.

Distribution 1 “thought process”

Link Speed	Cost (Revised IEEE Spec)
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100

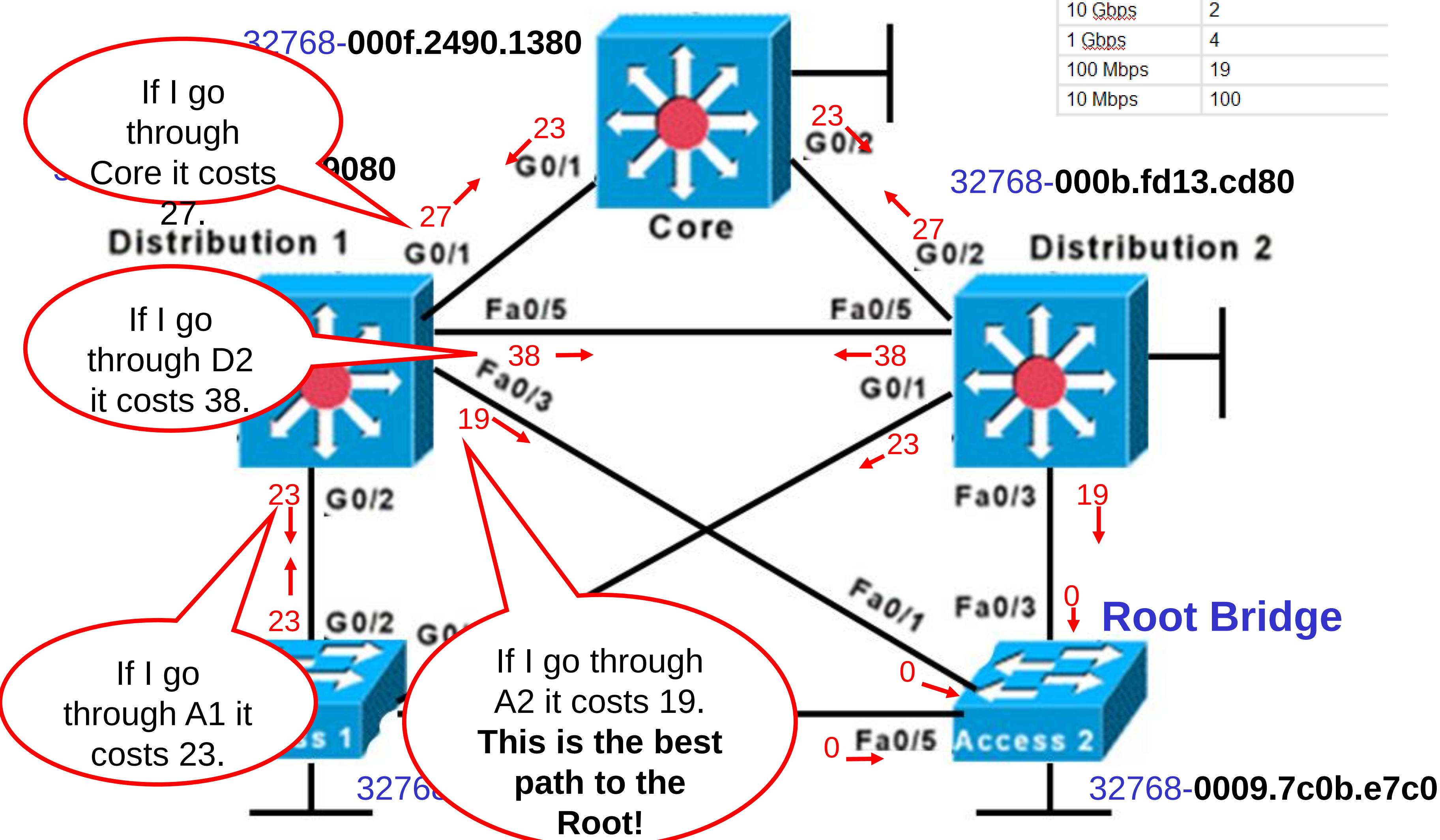


Elect Root Ports:

- This is from the ***switch's perspective***.
- Switch, "What is my cost to the Root Bridge?"
- Later we will look at Designated Ports, which is from the ***Segment's perspective***.

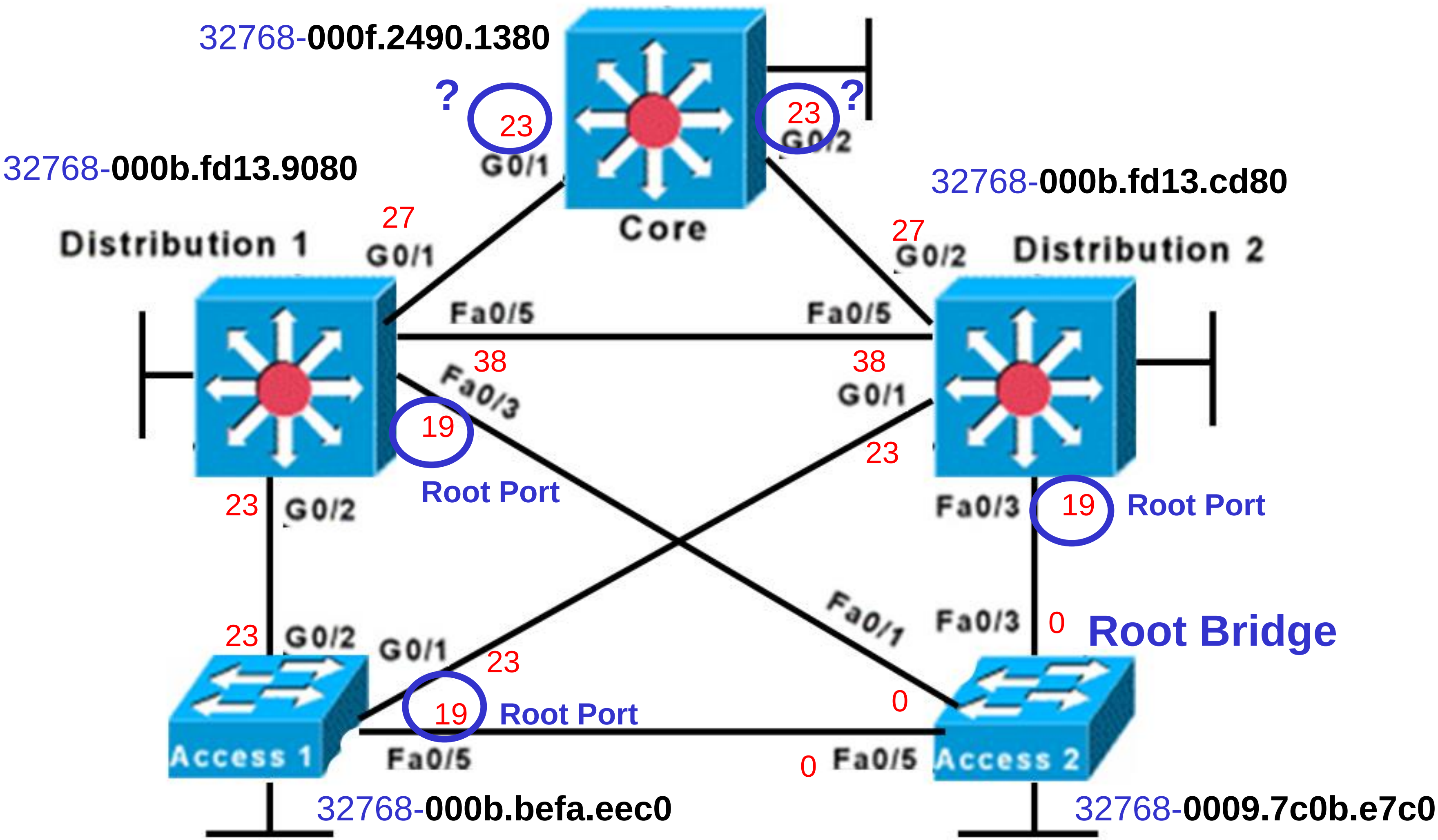
Distribution 1 "thought process"

Link Speed	Cost (Revised IEEE Spec)
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100



Elect Root Ports

- Every non-Root bridge must select one **Root Port**.
- A bridge's **Root Port** is the port closest to the Root Bridge.
- Bridges use the **cost** to determine closeness.

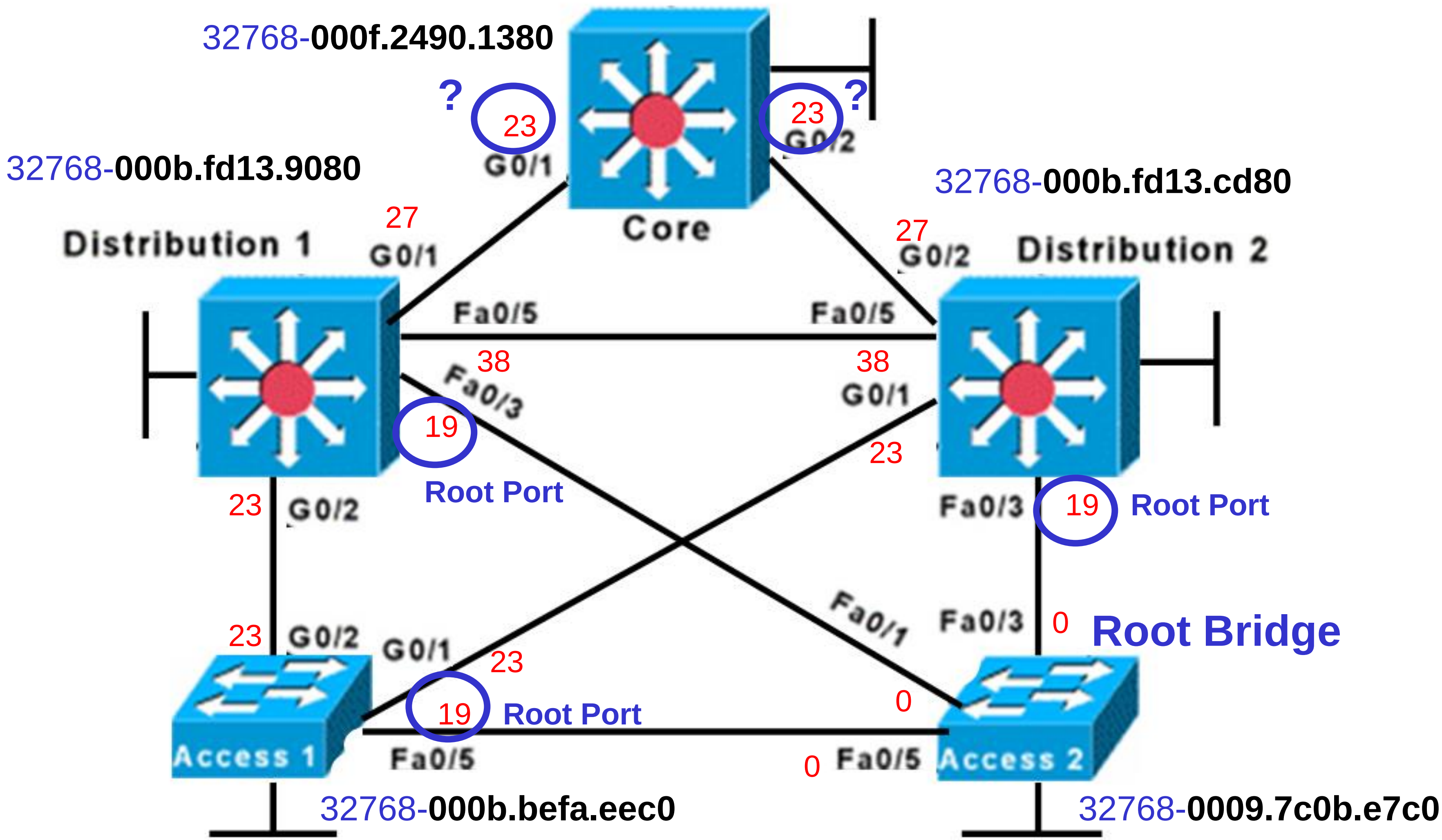


Elect Root Ports

- Core switch has two equal Root Path Costs to the Root Bridge.
- In this case we need to look at the five-step decision process.

Five-Step decision Sequence

Step 1 - Lowest BID
Step 2 - Lowest Path Cost to Root Bridge
Step 3 - Lowest Sender BID
Step 4 - Lowest Port Priority
Step 5 - Lowest Port ID

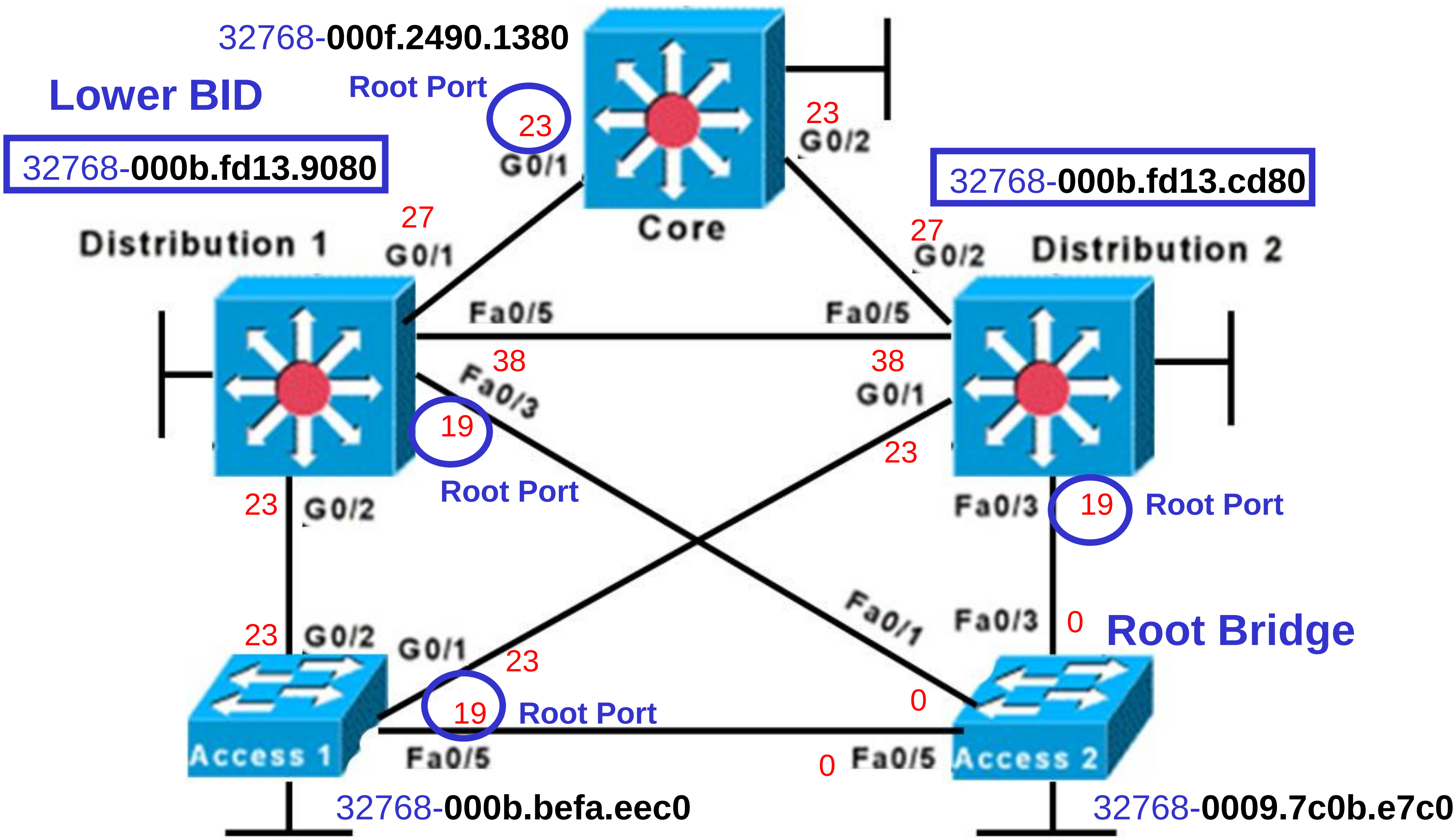


Elect Root Ports

- Distribution 1 switch has a lower Sender BID than Distribution 2.
- Core chooses the Root Port of G 0/1.

Five-Step decision Sequence

Step 1 - Lowest BID
Step 2 - Lowest Path Cost to Root Bridge
Step 3 - Lowest Sender BID
Step 4 - Lowest Port Priority
Step 5 - Lowest Port ID



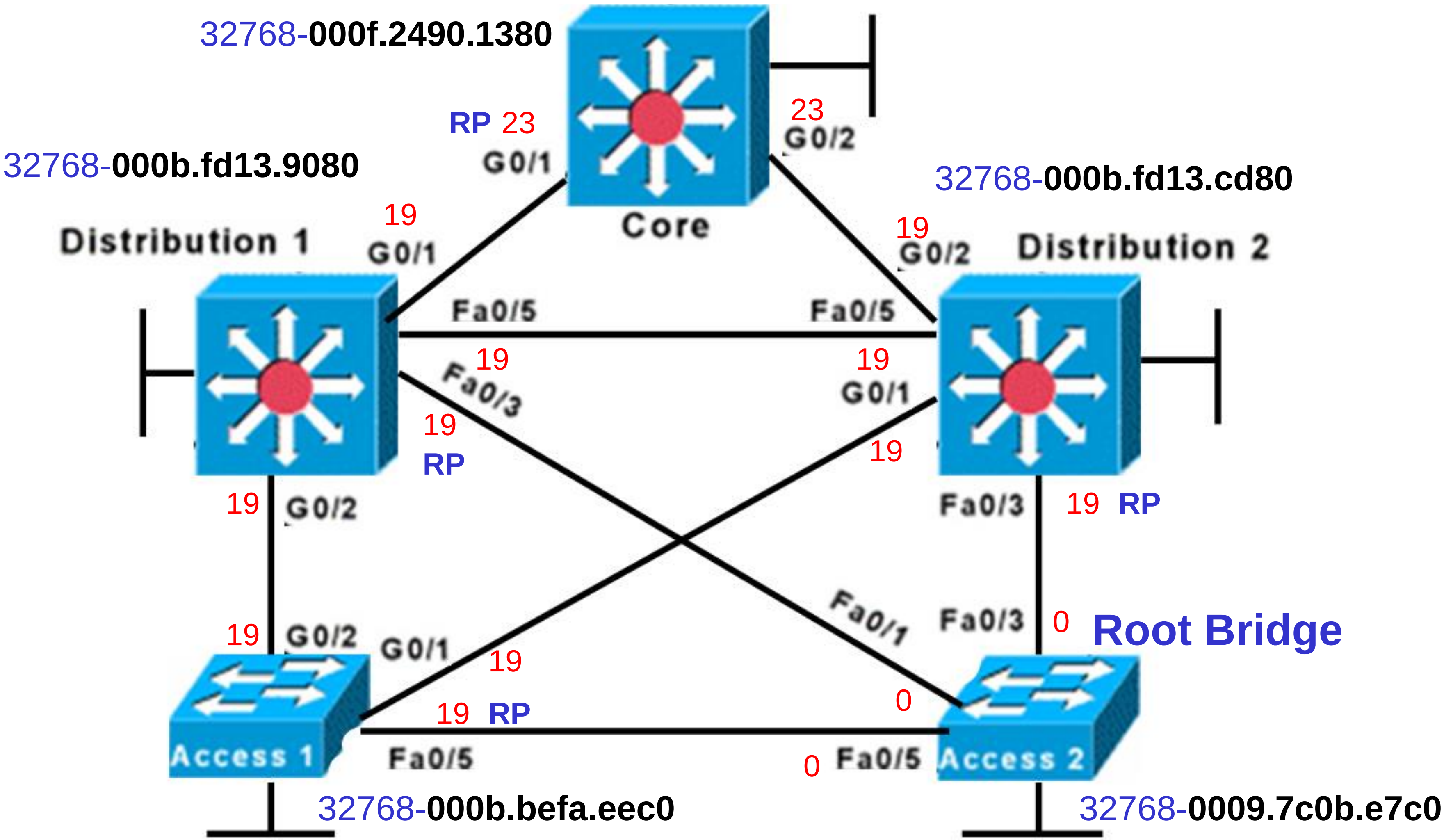
Elect Designated Ports

STP Convergence

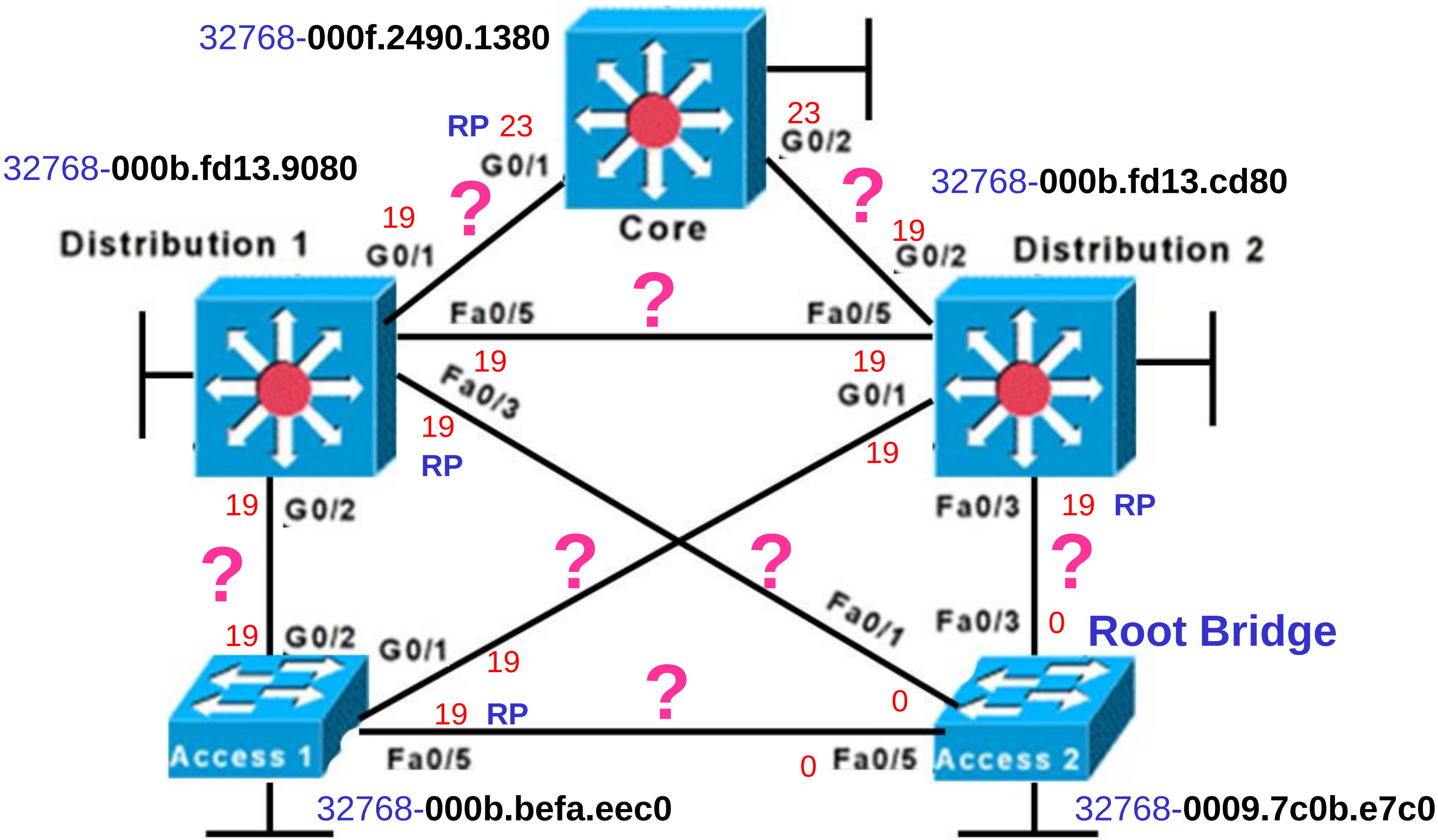
Step 1 Elect one Root Bridge
Step 2 Elect Root Ports
Step 3 Elect Designated Ports

- The loop prevention part of STP becomes evident during this step, electing designated ports.
- A Designated Port functions as the single bridge port that both sends and receives traffic to and from that segment and the Root Bridge.
- **Each segment in a bridged network has one Designated Port, chosen based on cumulative Root Path Cost to the Root Bridge.**
- The switch containing the **Designated Port** is referred to as the **Designated Bridge** for that segment.
- To locate Designated Ports, lets take a look at each segment.
- **Segment's perspective**: From a device on this segment, *"Which switch should I go through to reach the Root Bridge?"*
  - **Root Path Cost**, the cumulative cost of all links to the Root Bridge.
  - Obviously, the segment has not ability to make this decision, so the perspective and the decision is that of the switches on that segment.

- A **Designated Port** is elected for every segment.
- The **Designated Port** is the only port that sends and receives traffic to/from that segment to the Root Bridge, the best port towards the root bridge.
- **Note**: The Root Path Cost shows the ***Sent*** Root Path Cost.
- This is the advertised cost in the BPDU, by this switch out that interface, i.e. this is the cost of reaching the Root Bridge through me!

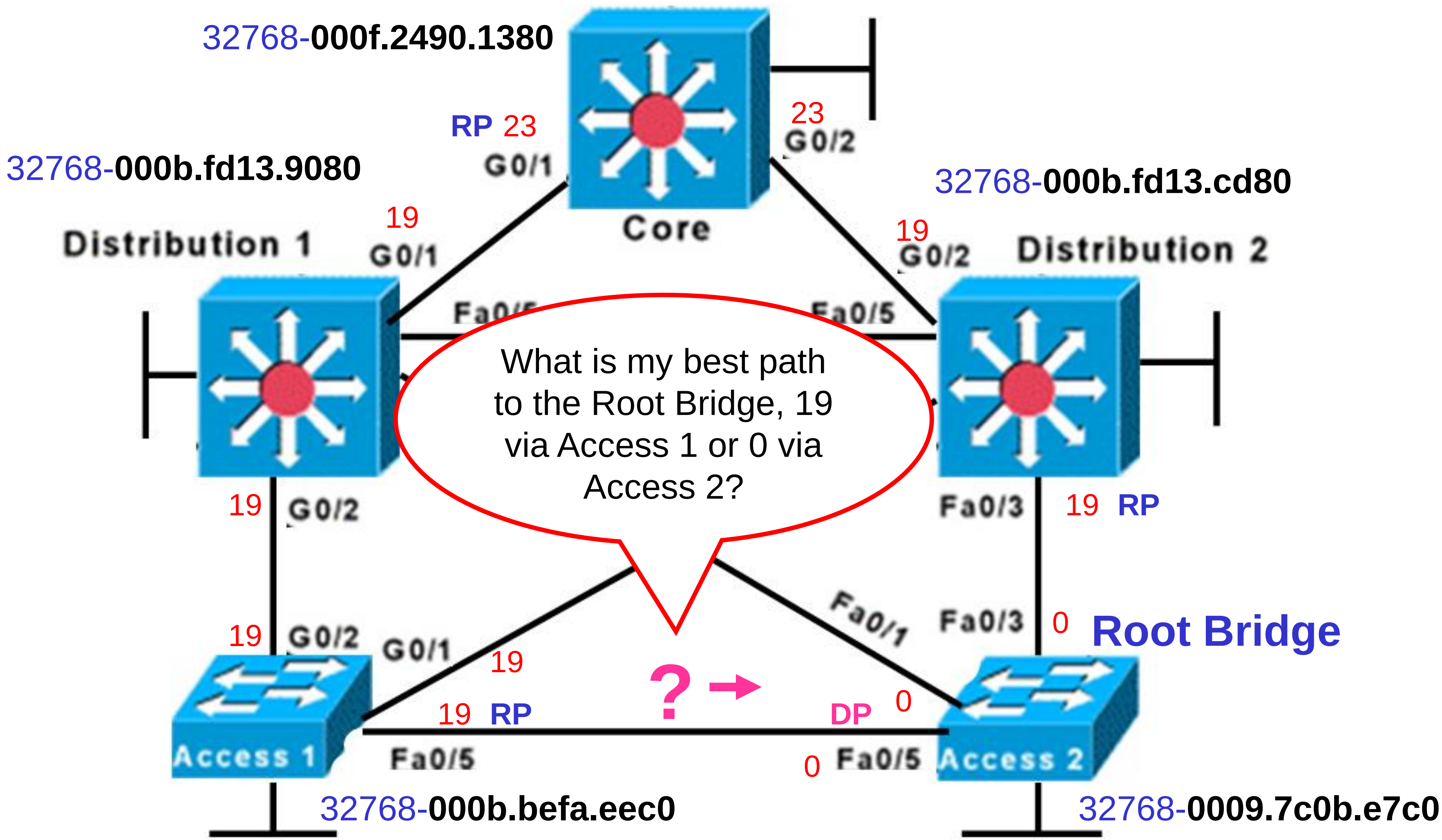


- A **Designated Port** is elected for every segment.
- **Segment's perspective**: From a device on this segment, *"Which switch should I go through to reach the Root Bridge?"*
- *"I'll decide using the advertised Root Path Cost from each switch!"*



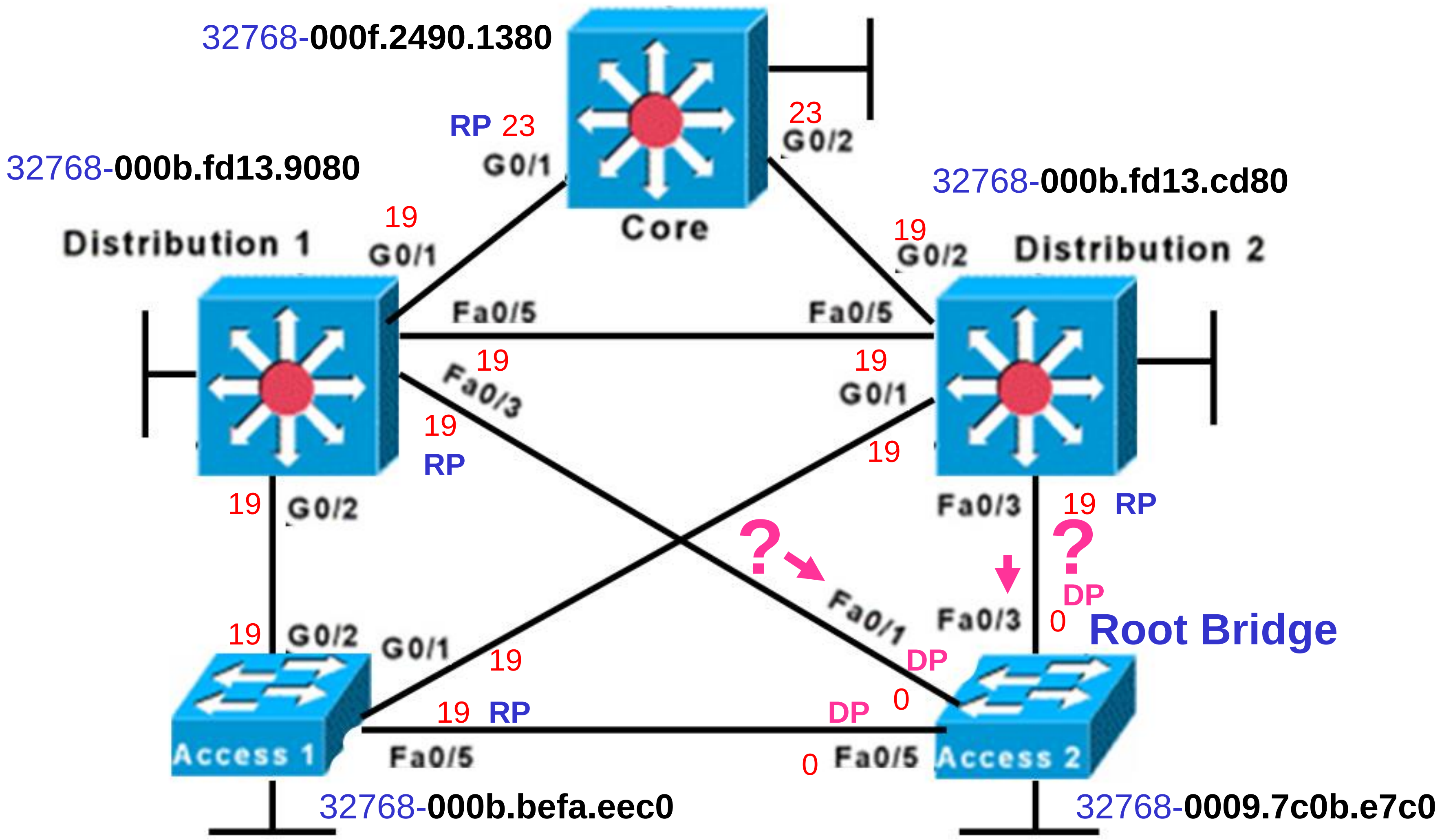
Segment's perspective:

- Access 2 has a Root Path Cost = 0 (after all it is the Root Bridge) and Access 1 has a Root Path Cost = 19.
- Because Access 2 has the lower Root Path Cost it becomes the **Designated Port** for that segment.



Segment's perspective:

- The same occurs between Access 2 and Distribution 1 and Distribution 2 switches.
- Because Access 2 has the lower Root Path Cost it becomes the **Designated Port** for those segments.

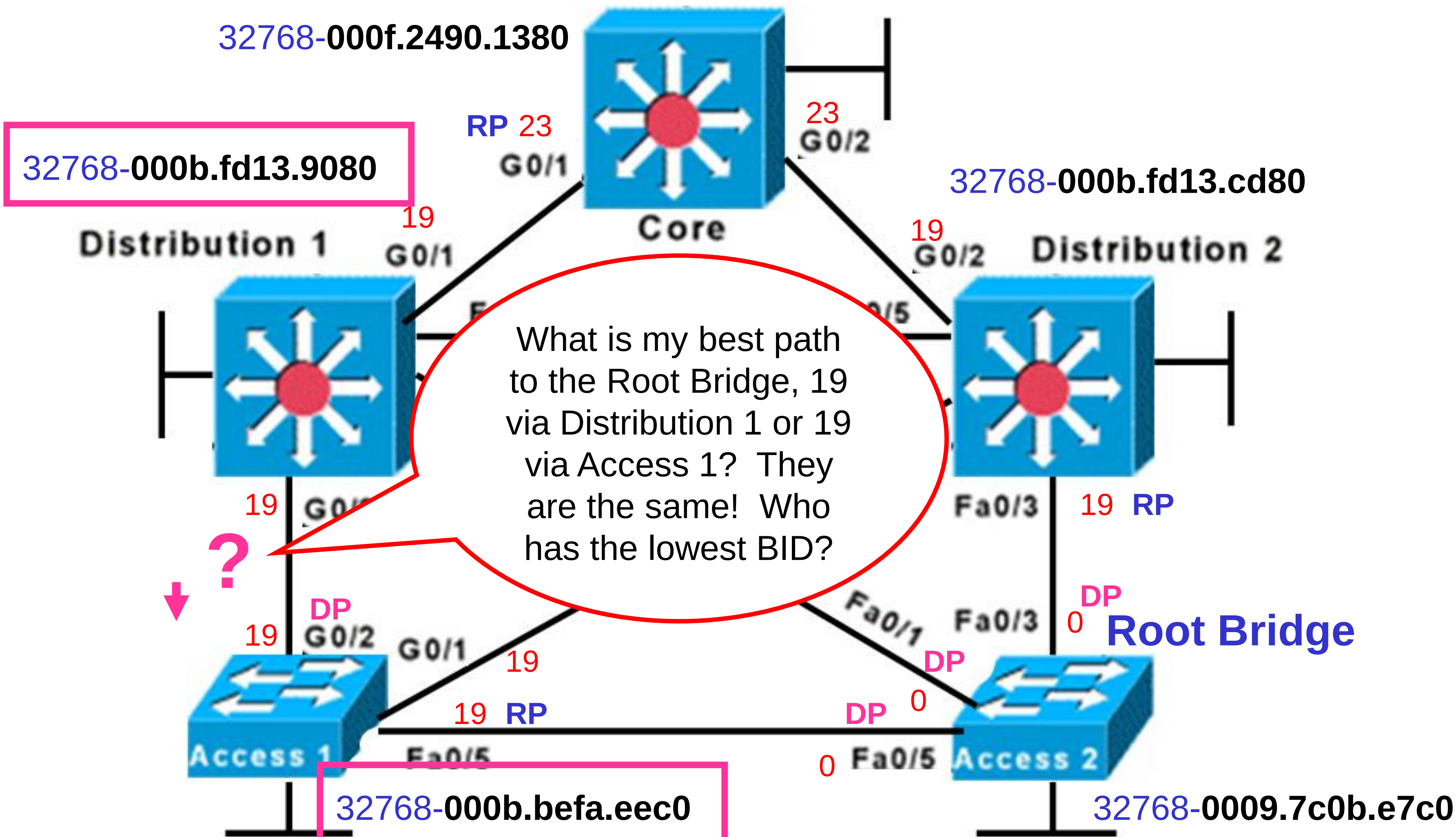


Segment's perspective:

- Segment between Distribution 1 and Access 1 has two equal Root Path Costs of 19.
- Using the Lowest Sender ID (first two steps are equal), **Access 1** becomes the best path and the **Designated Port**.

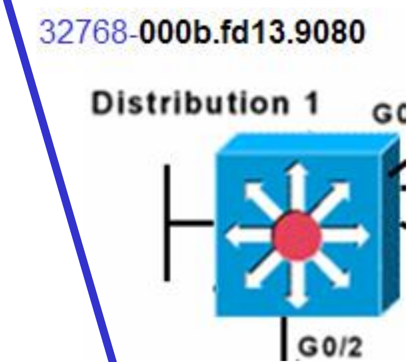
Five-Step decision Sequence

Step 1 - Lowest BID
Step 2 - Lowest Path Cost to Root Bridge
Step 3 - Lowest Sender BID
Step 4 - Lowest Port Priority
Step 5 - Lowest Port ID

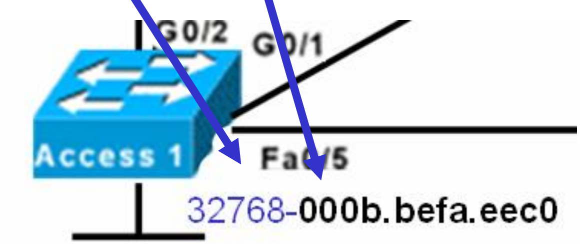


Access 1 has Lower Sender BID


```
Distribution1#show spanning-tree detail
 Port 26 (GigabitEthernet0/2) of VLAN0001 is blocking
   Port path cost 4, Port priority 128, Port Identifier 128.26.
   Designated root has priority 32769, address 0009.7c0b.e7c0
   Designated bridge has priority 32769, address 000b.befa.eec0
   Designated port id is 128.26, designated path cost 19
   Timers: message age 3, forward delay 0, hold 0
   Number of transitions to forwarding state: 0
   BPDU: sent 2, received 1070
```




```
Access1#show spanning-tree detail
 Port 26 (GigabitEthernet0/2) of VLAN0001 is forwarding
   Port path cost 4, Port priority 128, Port Identifier 128.26.
   Designated root has priority 32769, address 0009.7c0b.e7c0
   Designated bridge has priority 32769, address 000b.befa.eec0
   Designated port id is 128.26, designated path cost 19
   Timers: message age 0, forward delay 0, hold 0
   Number of transitions to forwarding state: 1
   BPDU: sent 2243, received 1
```



Segment's perspective:

- Segment between Distrib. 1 and Distrib. 2 has two equal Root Path Costs of 19.
- Using the Lowest Sender ID (first two steps are equal), **Distribution 1** becomes the best path and the **Designated Port**.

Five-Step decision Sequence

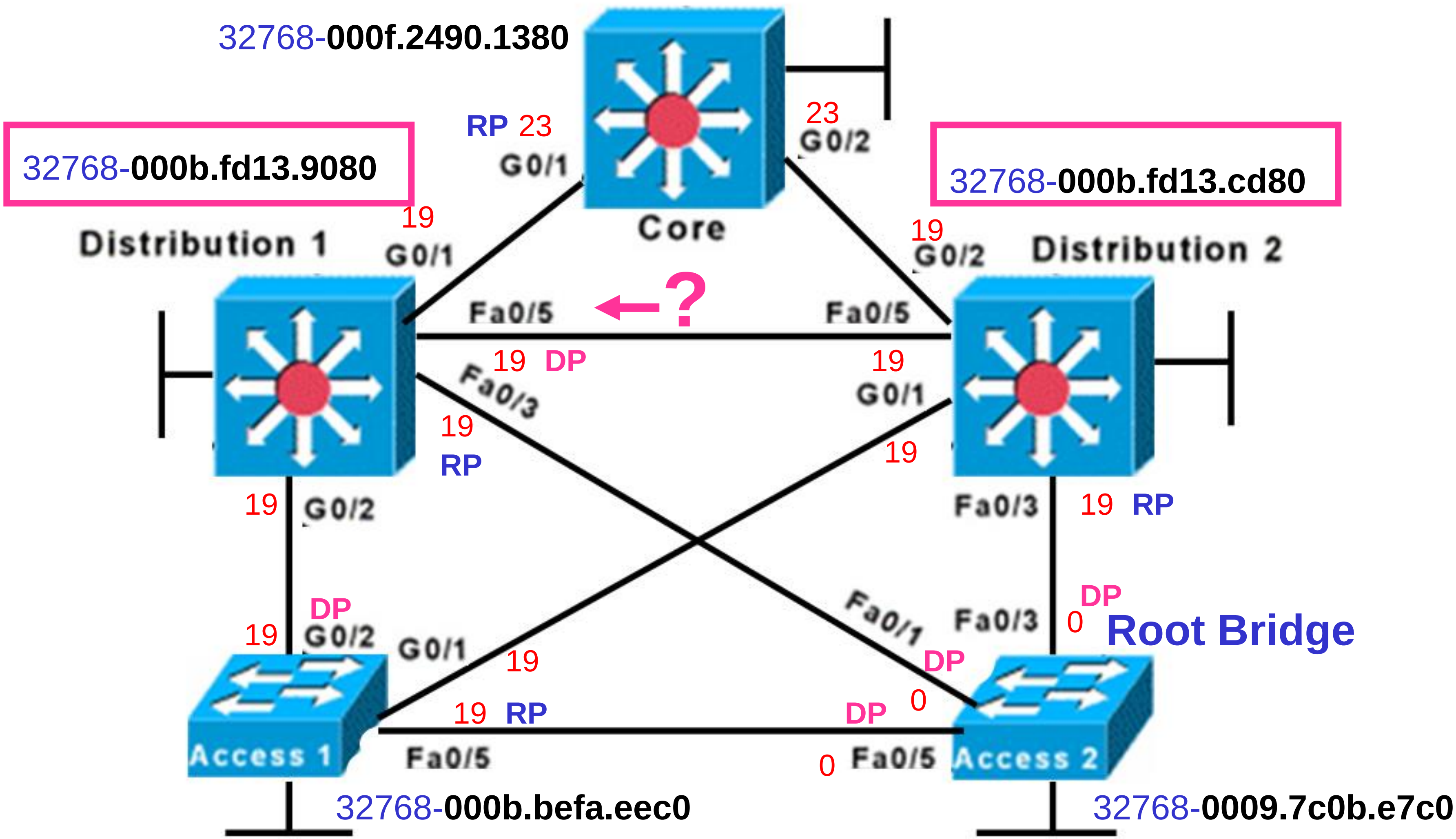
Step 1 - Lowest BID

Step 2 - Lowest Path Cost to Root Bridge

Step 3 - Lowest Sender BID

Step 4 - Lowest Port Priority

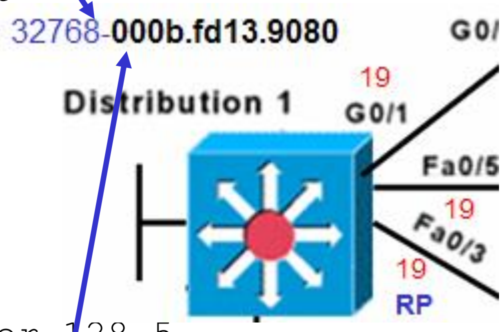
Step 5 - Lowest Port ID

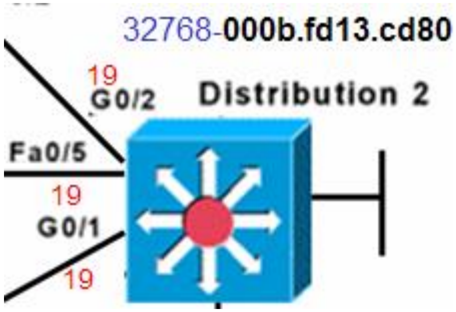


Distribution 1 has Lower Sender BID


```
Distribution1#show spanning-tree detail
 Port 5 (FastEthernet0/5) of VLAN0001 is forwarding
   Port path cost 19, Port priority 128, Port Identifier 128.5.
   Designated root has priority 32769, address 0009.7c0b.e7c0
   Designated bridge has priority 32769, address 000b.fd13.9080
   Designated port id is 128.5, designated path cost 19
   Timers: message age 0, forward delay 0, hold 0
   Number of transitions to forwarding state: 1
   BPDU: sent 1074, received 0

Distribution2#show spanning-tree detail
 Port 5 (FastEthernet0/5) of VLAN0001 is blocking
   Port path cost 19, Port priority 128, Port Identifier 128.5.
   Designated root has priority 32769, address 0009.7c0b.e7c0
   Designated bridge has priority 32769, address 000b.fd13.9080
   Designated port id is 128.5, designated path cost 19
   Timers: message age 2, forward delay 0, hold 0
   Number of transitions to forwarding state: 0
   BPDU: sent 0, received 1097
```





Segment's perspective:

- Segment between Access 1 and Distrib. 2 has two equal Root Path Costs of 19.
- Using the Lowest Sender ID (first two steps are equal), **Access 1** becomes the best path and the **Designated Port**.

Five-Step decision Sequence

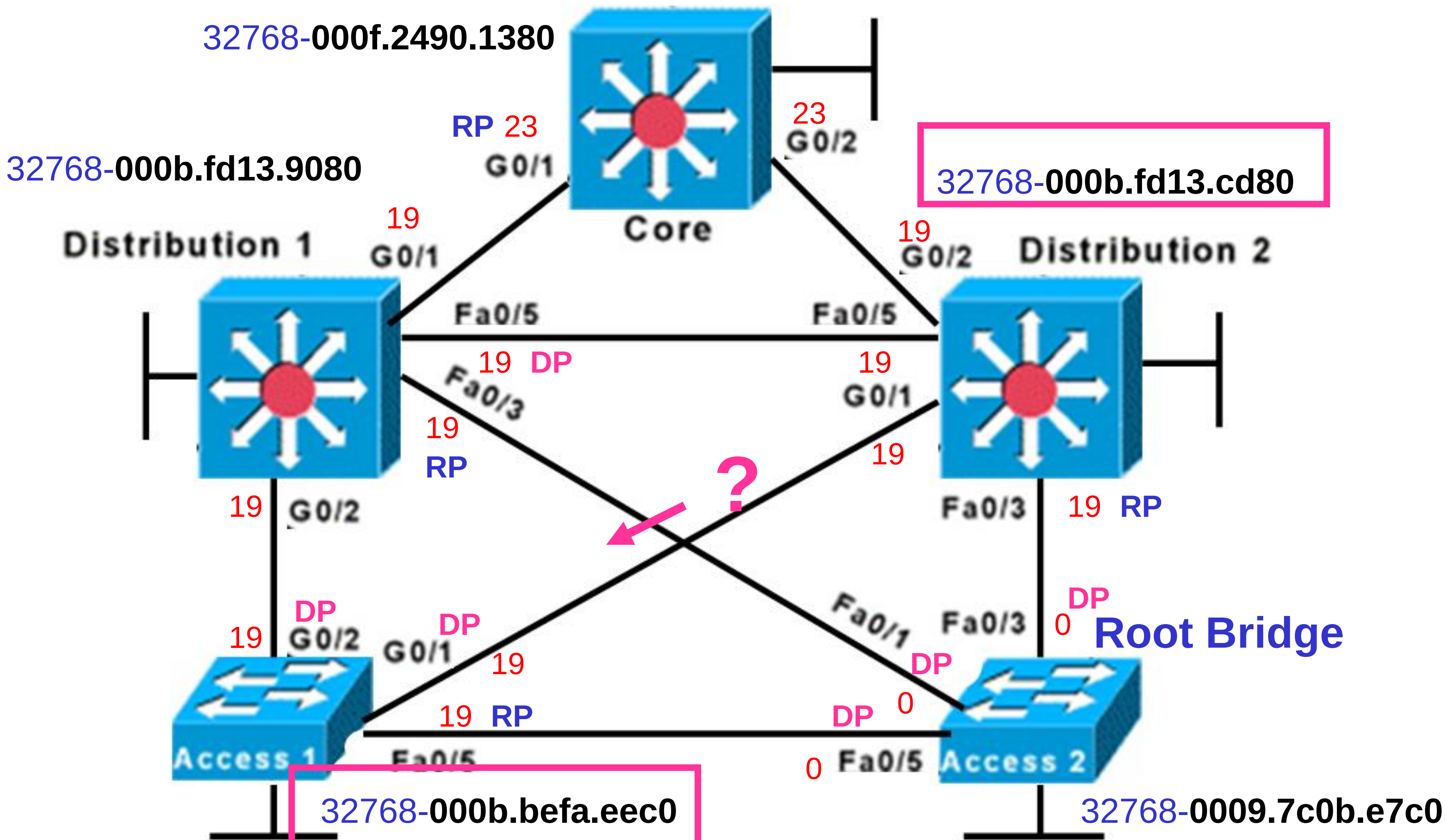
Step 1 - Lowest BID

Step 2 - Lowest Path Cost to Root Bridge

Step 3 - Lowest Sender BID

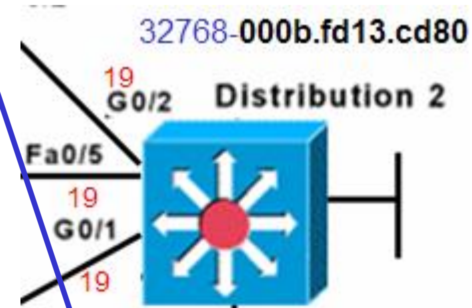
Step 4 - Lowest Port Priority

Step 5 - Lowest Port ID

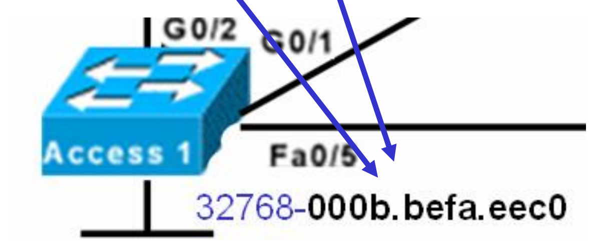


Access 1 has Lower Sender BID


```
Distribution2#show spanning-tree detail
 Port 25 (GigabitEthernet0/1) of VLAN0001 is blocking
   Port path cost 4, Port priority 128, Port Identifier 128.25.
   Designated root has priority 32769, address 0009.7c0b.e7c0
   Designated bridge has priority 32769, address 000b.befa.eec0
   Designated port id is 128.25, designated path cost 19
   Timers: message age 3, forward delay 0, hold 0
   Number of transitions to forwarding state: 0
   BPDU: sent 2, received 1091
```

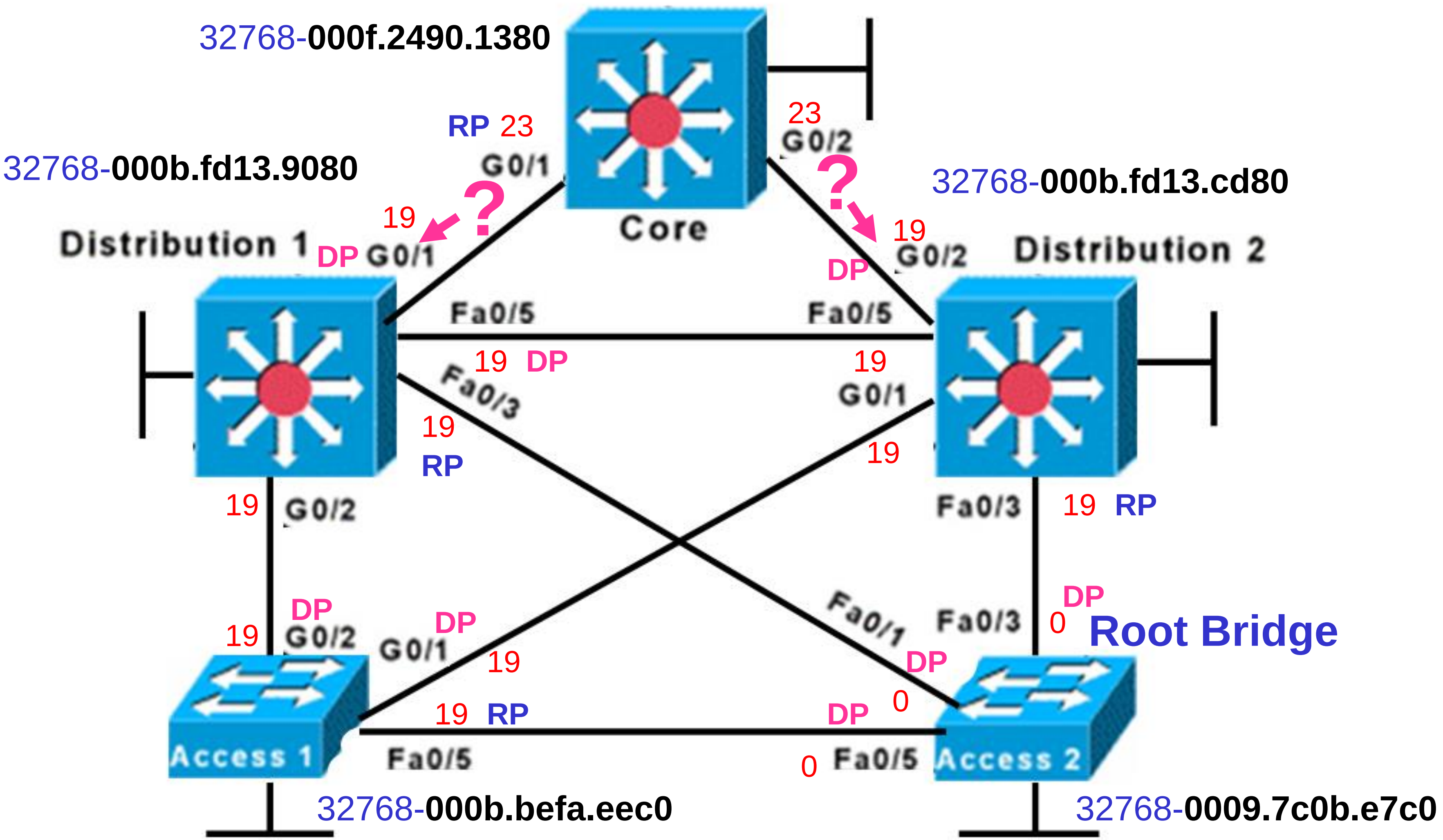



```
Access1#show spanning-tree detail
 Port 25 (GigabitEthernet0/1) of VLAN0001 is forwarding
   Port path cost 4, Port priority 128, Port Identifier 128.25.
   Designated root has priority 32769, address 0009.7c0b.e7c0
   Designated bridge has priority 32769, address 000b.befa.eec0
   Designated port id is 128.25, designated path cost 19
   Timers: message age 0, forward delay 0, hold 0
   Number of transitions to forwarding state: 1
   BPDU: sent 2240, received 1
```



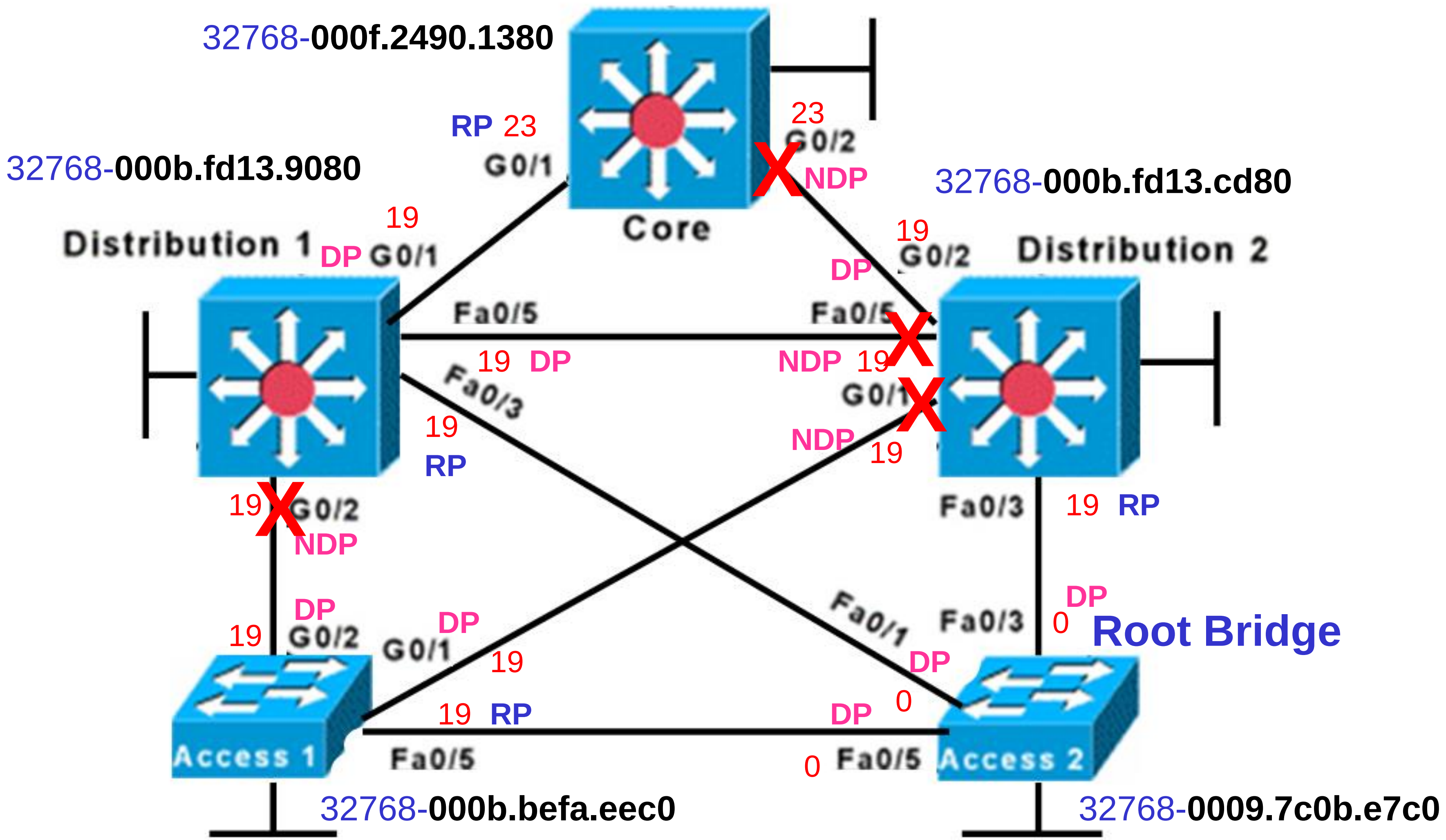
Segment's perspective:

- Because **Distribution 1** has the lower Root Path Cost it becomes the **Designated Port** for that segment.
- Because **Distribution 2** has the lower Root Path Cost it becomes the **Designated Port** for that segment.

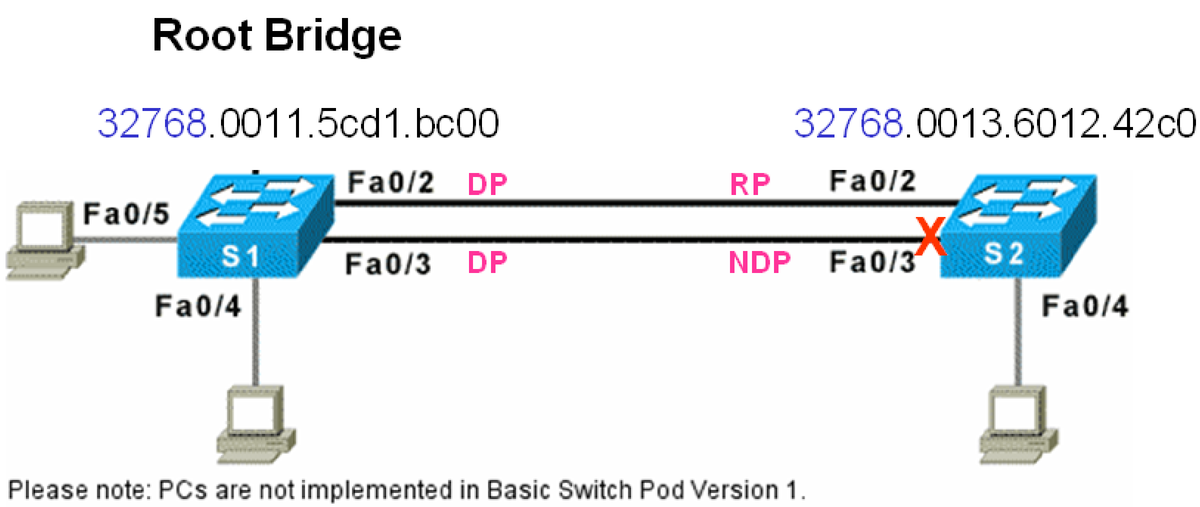


Segment’s perspective:

- All other ports, those ports that are not Root Ports or Designated Ports, become **Non-Designated Ports.**
- **Non-Designated Ports** are put in blocking mode. (Coming)
- This is the loop prevention part of STP.



Port Cost/Port ID

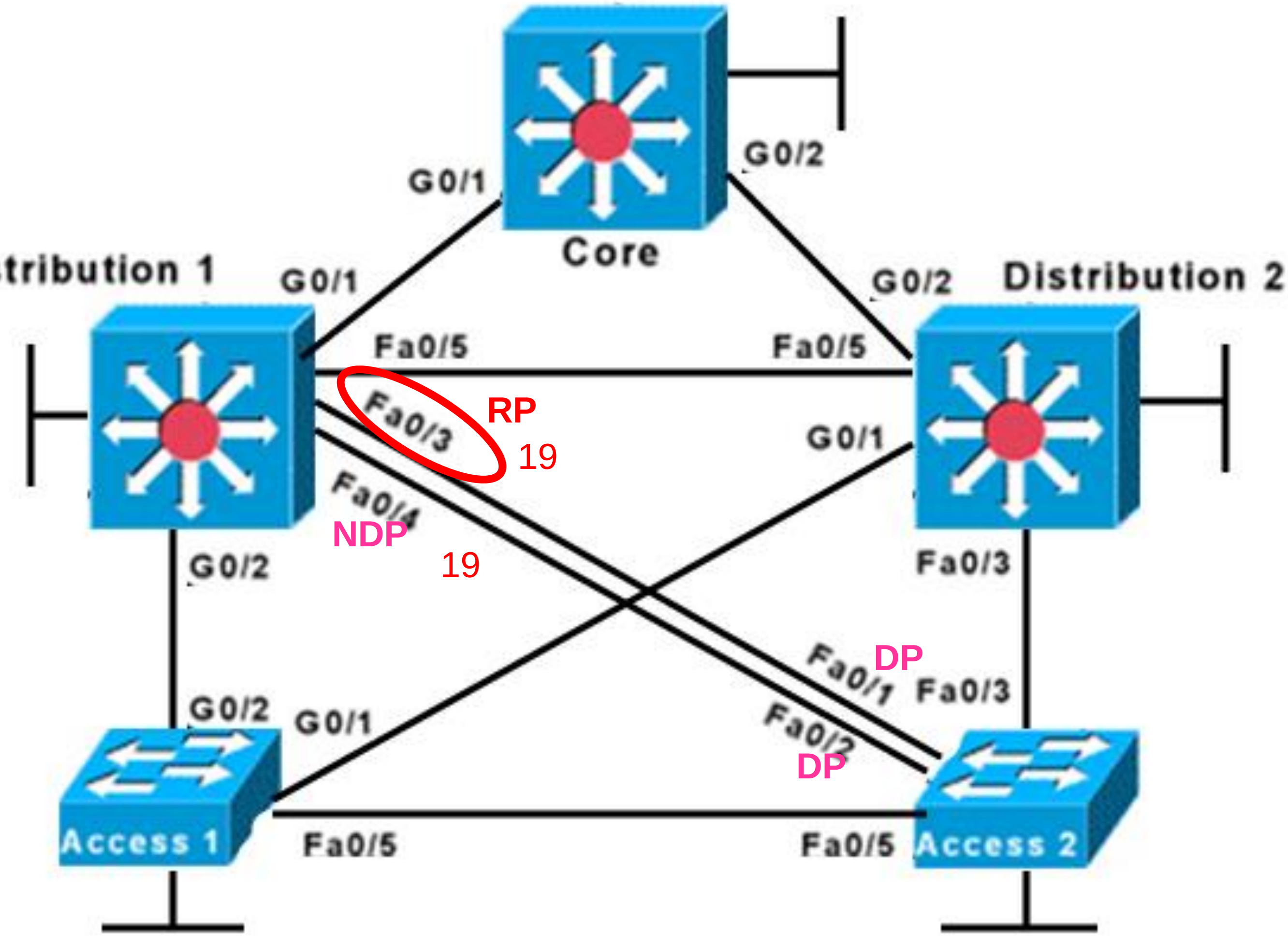


Port 0/2 would forward because it's the lowest.

- If the path cost and bridge IDs are equal (as in the case of parallel links), the switch goes to the port priority as a tiebreaker.
- Lowest port priority wins (all ports set to 32).
- You can set the priority from 0 – 63.
- If all ports have the same priority, the port with the lowest port number forwards frames.

Port Cost/Port ID

- Fa 0/3 has a lower Port ID than Fa 04.
- Multiple links can be configured (used) as a single connection, using EtherChannel (CCNP 3).



Port Cost/Port ID

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```
Distribution1#show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32769
             Address     0009.7c0b.e7c0
             Cost        19
             Port        3 (FastEthernet0/3)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000b.fd13.9080
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300
Interface        Port ID                     Designated            Port ID
Name             Prio.Nbr      Cost Sts      Cost Bridge ID            Prio.Nbr
---------------- -------- --------- --- --------- -------------------- --------
Fa0/1            128.1           19 BLK        19 32769 000b.befa.eec0 128.1
Fa0/2            128.2           19 BLK        19 32769 000b.befa.eec0 128.2
Fa0/3            128.3           19 FWD         0 32769 0009.7c0b.e7c0 128.1
Fa0/4            128.4           19 BLK         0 32769 0009.7c0b.e7c0 128.2
Fa0/5            128.5           19 FWD        19 32769 000b.fd13.9080 128.5
Gi0/1            128.25           4 FWD        19 32769 000b.fd13.9080 128.25
```

STP Convergence: Summary

Example:

- A network that contains 15 switches and 146 segments (every switchport is a unique segment) would result in:
  - 1 Root Bridge
  - 14 Root Ports
  - 146 Designated Ports

Spanning-Tree Port States

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State	Purpose
Forwarding	Sending / receiving user data
Learning	Building bridging table
Listening	Building "active" topology
Blocking	Receives BPDUs only
Disabled	Administratively down

STP Timers

Timer	Primary Purpose	Default
Hello Time	Time between sending of Configuration BPDUs by the Root Bridge	2 Secs
Forward Delay	Duration of Listening and Learning States	15 Secs
Max Age	Time BPDU stored	20 Secs

Spanning Tree Port States

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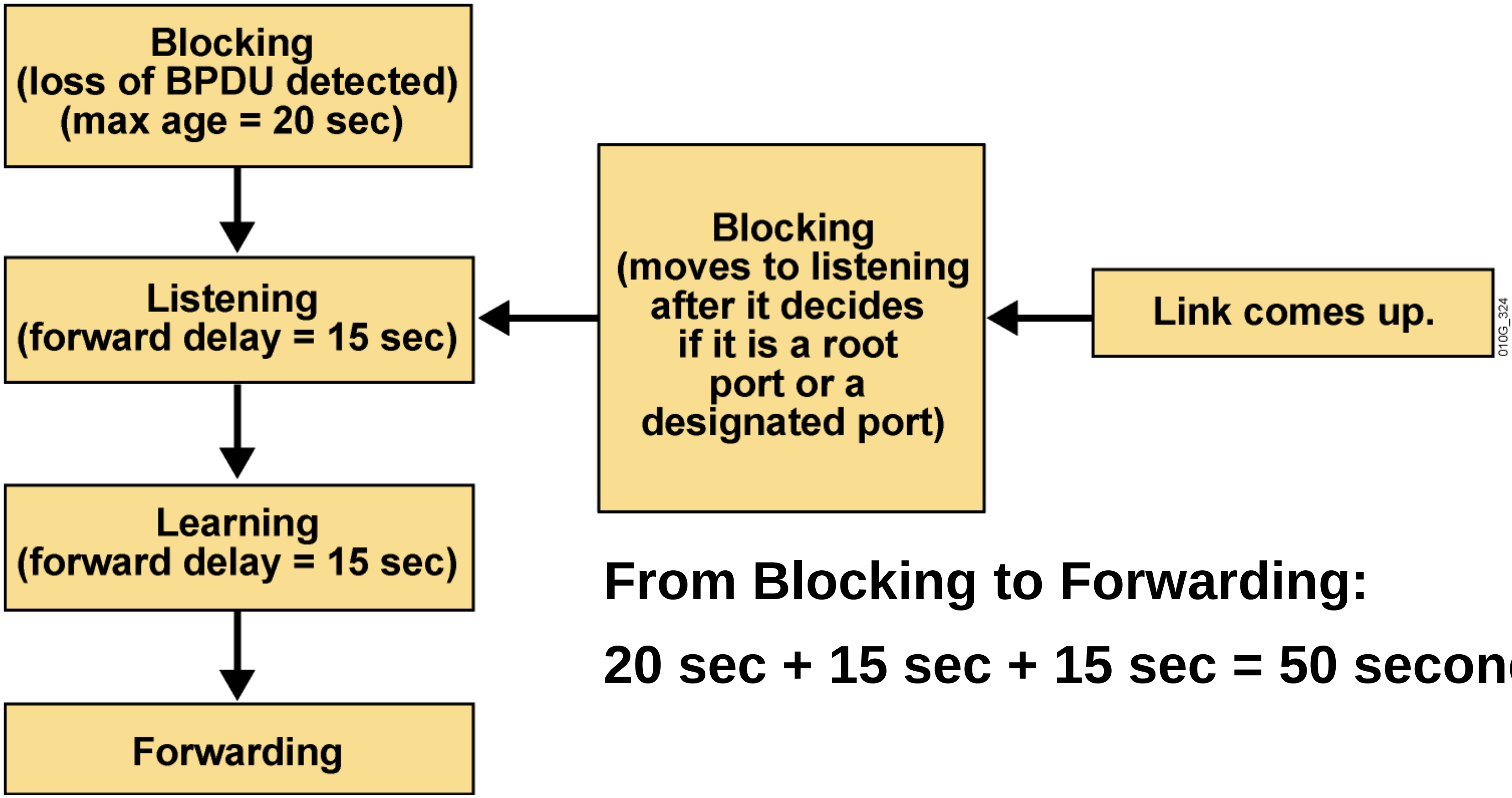
Spanning tree transitions each port through several different states.



From Blocking to Forwarding:

20 sec + 15 sec + 15 sec = 50 seconds

Spanning-Tree Port States

Blocked:

- All ports start in blocked mode in order to prevent the bridge from creating a bridging loop.
- Port are listening (receiving) BPDUs.
- **No user data is being passed**.
- The port stays in a blocked state if Spanning Tree determines that there is a **better path to the root bridge**.
- May take a port up to 20 seconds to transition out of this state (max age). - coming soon.

BPDUs sent and received

State	Purpose
Forwarding	Sending / receiving user data
Learning	Building bridging table
Listening	Building "active" topology
Blocking	Receives BPDUs only
Disabled	Administratively down

Spanning-Tree Port States

Listen:

- The port transitions from the blocked state to the listen state
- Attempts to learn whether there are any other paths to the root bridge
- **Listens to frames**
- Port is **not sending or receive user data**
- Listens for a period of time called the forward delay (default 15 seconds).
- Ports that lose the *Designated Port election* become **non-Designated Ports** and drop back to **Blocking** state.

BPDUs sent and received

State	Purpose
Forwarding	Sending / receiving user data
Learning	Building bridging table
Listening	Building "active" topology
Blocking	Receives BPDUs only
Disabled	Administratively down

Spanning-Tree Port States

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Learn:

- The learn state is very similar to the listen state, except that the port can add information it has learned to its address table.
- **Adds addresses to MAC Address Table**
- Still **not allowed to send or receive user data**
- Learns for a period of time called the forward delay (default 15 seconds)

BPDUs sent and received

State	Purpose
Forwarding	Sending / receiving user data
Learning	Building bridging table
Listening	Building "active" topology
Blocking	Receives BPDUs only
Disabled	Administratively down

Spanning-Tree Port States

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Forward:

- The port can **send and receive user data**.
- A port is placed in the forwarding state if:
  - There are no redundant links

  or

  - It is determined that it has the best path to the root

BPDUs sent and received

State	Purpose
Forwarding	Sending / receiving user data
Learning	Building bridging table
Listening	Building "active" topology
Blocking	Receives BPDUs only
Disabled	Administratively down

Spanning-Tree Port States

- Disabled: The port is shutdown.

State	Purpose
Forwarding	Sending / receiving user data
Learning	Building bridging table
Listening	Building "active" topology
Blocking	Receives BPDUs only
Disabled	Administratively down

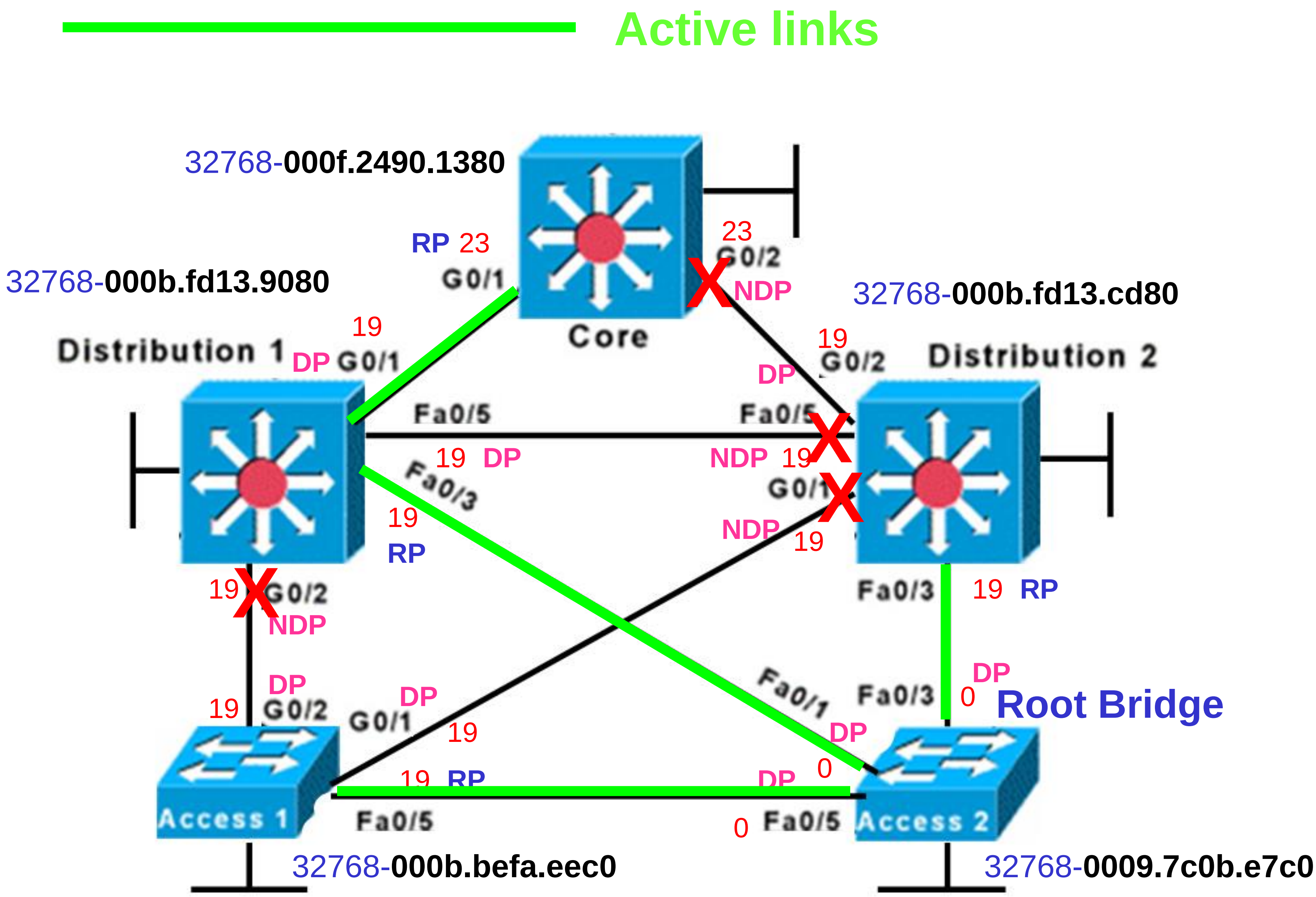
Spanning-Tree Port States

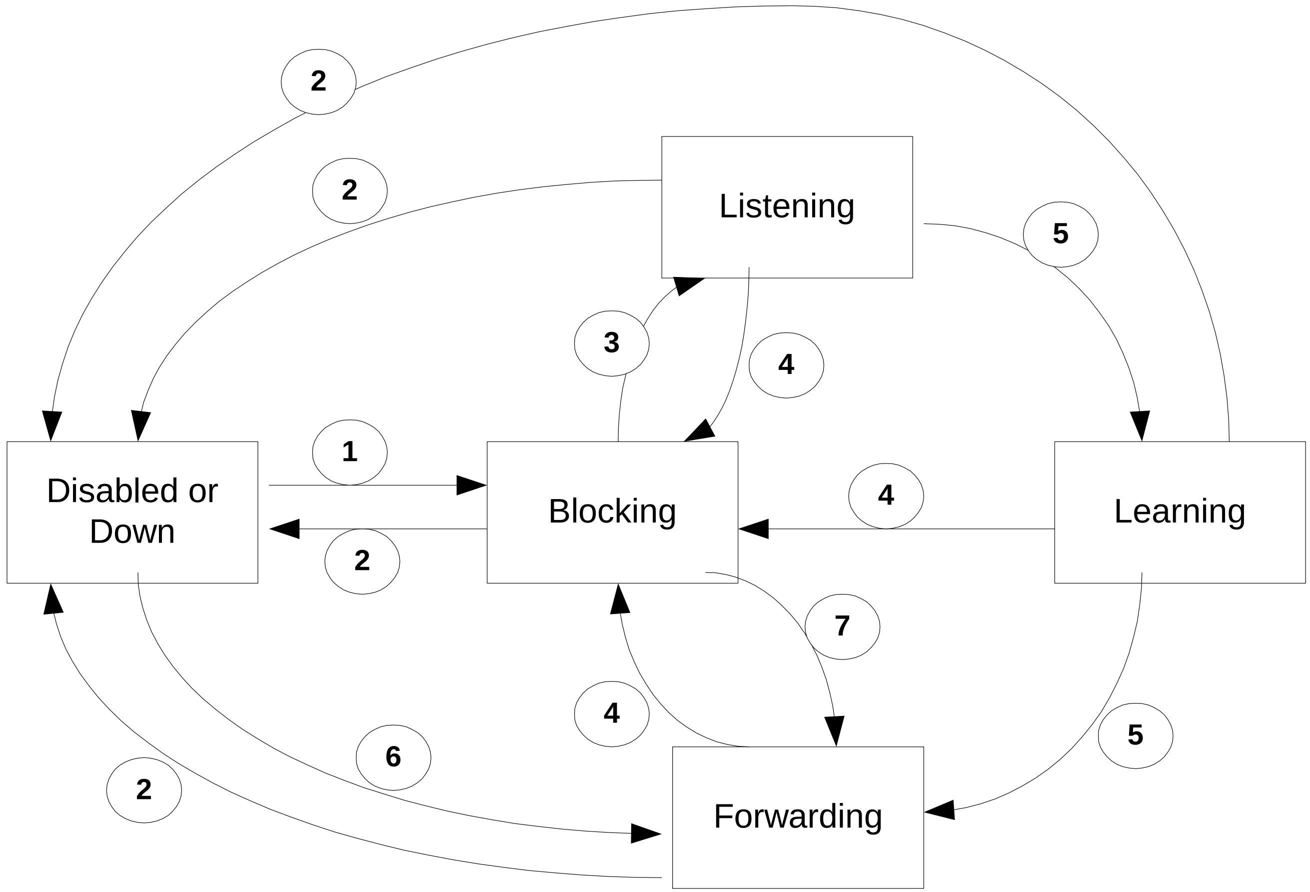
State	Purpose
Forwarding	Sending / receiving user data
Learning	Building bridging table
Listening	Building "active" topology
Blocking	Receives BPDUs only
Disabled	Administratively down

Designated Ports & Root Ports

Non-Designated Ports

Spanning-Tree Port States





Standard States
(1) Port enabled or initialized
(2) Port disabled or failed
(3) Port selected as Root or Designated Port
(4) Port ceases to be a Root or Designated Port
(5) Forwarding timer expires

Cisco Specific States
(6) PortFast
(7) Uplink Fast

Topology Change

- Much of the detail has been omitted.
- If there is a change in the topology, a link is added or removed:
  - User traffic will be disrupted until the switch recalculates paths using the Spanning Tree Algorithm.
  - A delay of up to 50 seconds may occur before switches start forwarding frames.

RSTP – IEEE 802.1w
(Rapid Spanning Tree Protocol)

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Rick Graziani

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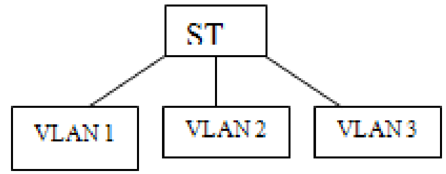
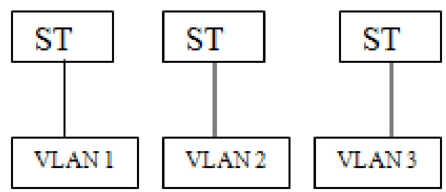
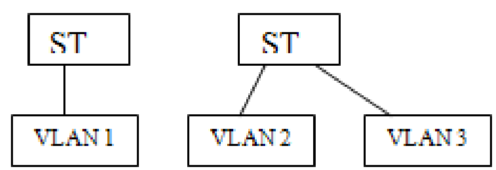
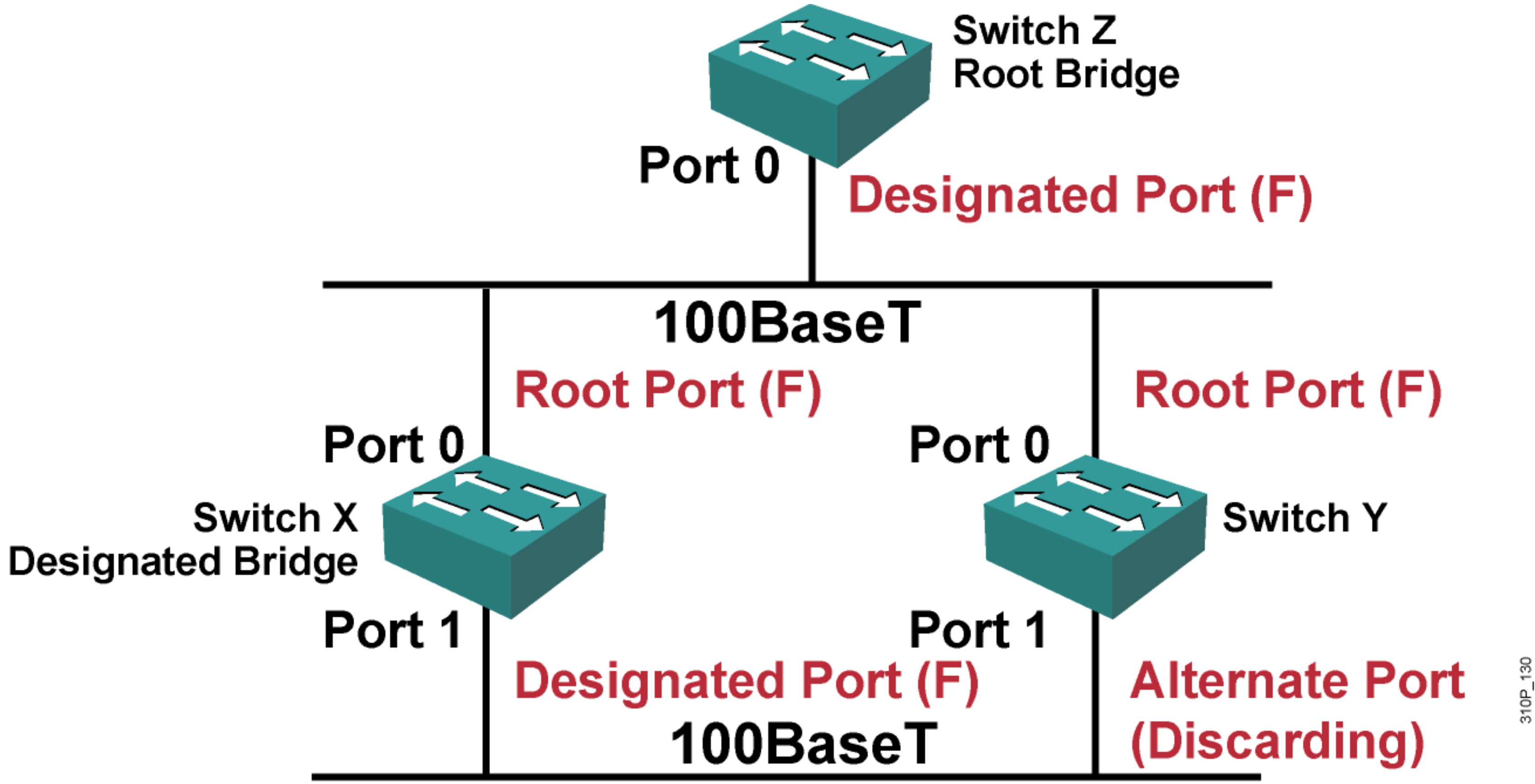
Evolution of STP

Cisco's Implementation	Spanning Tree Protocol Process	IEEE Standard
Spanning Tree Protocol (STP): • 802.1D • Common Spanning Tree (CST) • Mono Spanning Tree (MST)	ST = Spanning Tree 	
Cisco Enhancements (First evolution): • Portfast • Uplinkfast • Backbonefast		RSTP: • 802.1w • Edge Fast (Cisco Port Fast) • Uplink Fast RSTP (Cisco Uplink Fast) • Backbone Fast Engine (Cisco Backbone Fast)

Cisco Enhancements (Second Evolution):
• PVST: ISL
• PVST+: ISL & 802.1Q
• Includes previous enhancements
• Additional enhancements:
  o BPDU Guard
  o Root Guard
		

Cisco MISTP: • Uses PVST+ • Includes previous enhancements • Catalyst 4000/6000		MST (Multiple Spanning Tree): • 802.1s • Uses RSTP

Rapid Spanning Tree Protocol



Rapid Spanning Tree Protocol

- The immediate hindrance of STP is convergence.
- Depending on the type of failure, it takes anywhere from **30 to 50 seconds**, to converge the network.
- **RSTP helps with convergence** issues that plague legacy STP.

RSTP vs STP

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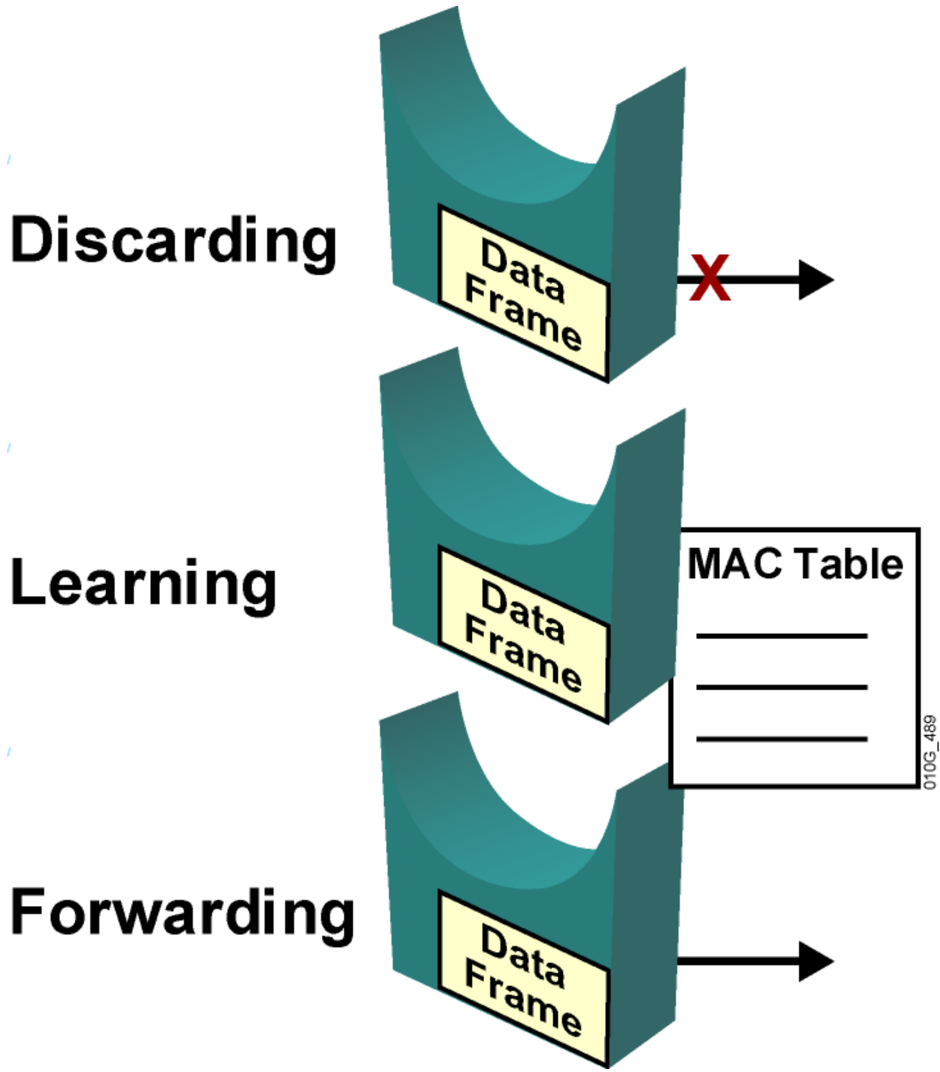
- RSTP is based on IEEE 802.1w standard.
- Numerous **differences** exist between RSTP and STP.
- ***RSTP requires full-duplex point-to-point connection between adjacent switches*** to achieve fast convergence.
  - Half duplex, denotes a shared medium, multiple devices.
  - As a result, RSTP cannot achieve fast convergence in half-duplex mode.
- STP and RSTP also have **port designation differences**.
  - RSTP has **alternate port** and **backup port** designations.
  - Ports ***not participating in spanning tree*** are known as **edge ports**.
  - The edge port becomes a **nonedge port** immediately if a BPDU is heard on the port.

RSTP vs STP

- RSTP is proactive and therefore negates the need for the 802.1D delay timers.
- RSTP (802.1w) supersedes 802.1D, while still remaining backward compatible.
- RSTP BPDU format is the same as the IEEE 802.1D BPDU format, except that the Version field is set to 2 to indicate RSTP.
- The RSTP spanning tree algorithm (STA) elects a root bridge in exactly the same way as 802.1D elects a root.
- Critical differences that make RSTP the preferred protocol for preventing Layer 2 loops in a switched network environment.
- Many of the differences stem from the Cisco proprietary enhancements. (CCNP 3)

RSTP Port States



RSTP Port States

Port State	Description
Discarding	•This state is seen in both a stable **active topology and during topology synchronization** and changes. •The discarding state **prevents the forwarding of data frames**, thus “breaking” the continuity of a Layer 2 loop.
Learning	•This state is seen in both a stable **active topology and during topology synchronization** and changes. •The learning state **accepts data frames to populate the MAC table** in an effort to limit flooding of unknown unicast frames.
Forwarding	•This state is seen **only in stable active topologies**. •The **forwarding** switch ports determine the topology. • Following a topology change, or during synchronization, the forwarding of data frames occurs only after a proposal and agreement process.

Port States

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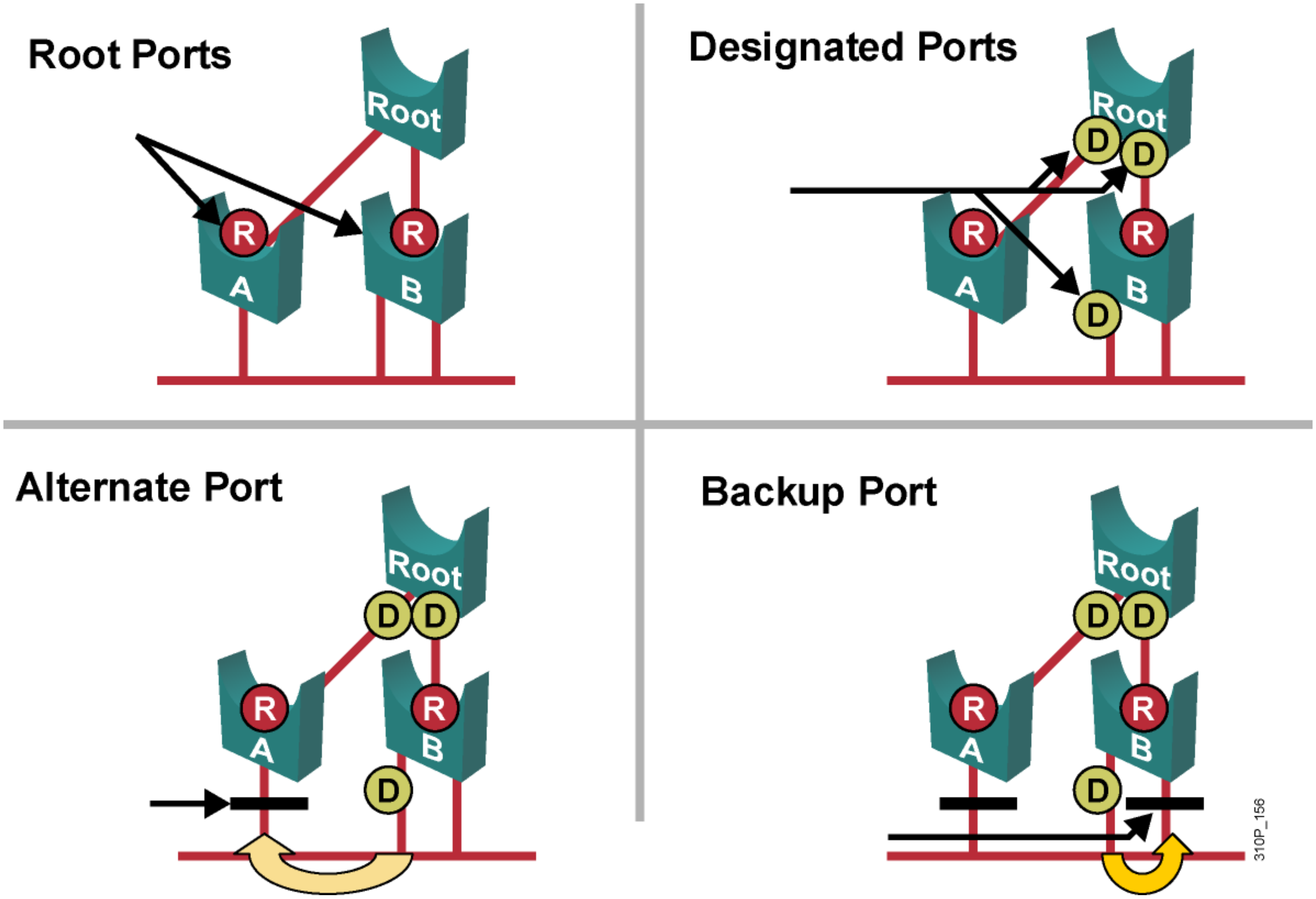
The table describes STP and RSTP port states.

Operational Port State	STP Port State	RSTP Port State
Enabled	Blocking	Discarding
Enabled	Listening	Discarding
Enabled	Learning	Learning
Enabled	Forwarding	Forwarding
Disabled	Disabled	Discarding

RSTP Port Roles



Port Roles

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Port Role	Description
Root port (Same as STP)	The root port is the switch port on every nonroot bridge that is the chosen path to the root bridge. There can be only one root port on every switch. The root port assumes the forwarding state in a stable active topology.
Designated port (Same as STP)	Each segment has at least one switch port as the designated port for that segment. In a stable, active topology, the switch with the designated port receives frames on the segment that are destined for the root bridge. There can be only one designated port per segment. The designated port assumes the forwarding state. All switches connected to a given segment listen to all BPDUs and determine the switch that will be the designated switch for a particular segment.
Alternative port (Non-Designated Port in STP)	The alternative port is a switch port that offers an alternative path toward the root bridge. The alternative port assumes a discarding state in a stable, active topology. An alternative port is present on nondesignated switches and makes a transition to a designated port if the current designated path fails.
Backup port	The backup port is an additional switch port on the designated switch with a redundant link to the segment for which the switch is designated. A backup port has a higher port ID than the designated port on the designated switch. The backup port assumes the discarding state in a stable, active topology.

RSTP Link Types

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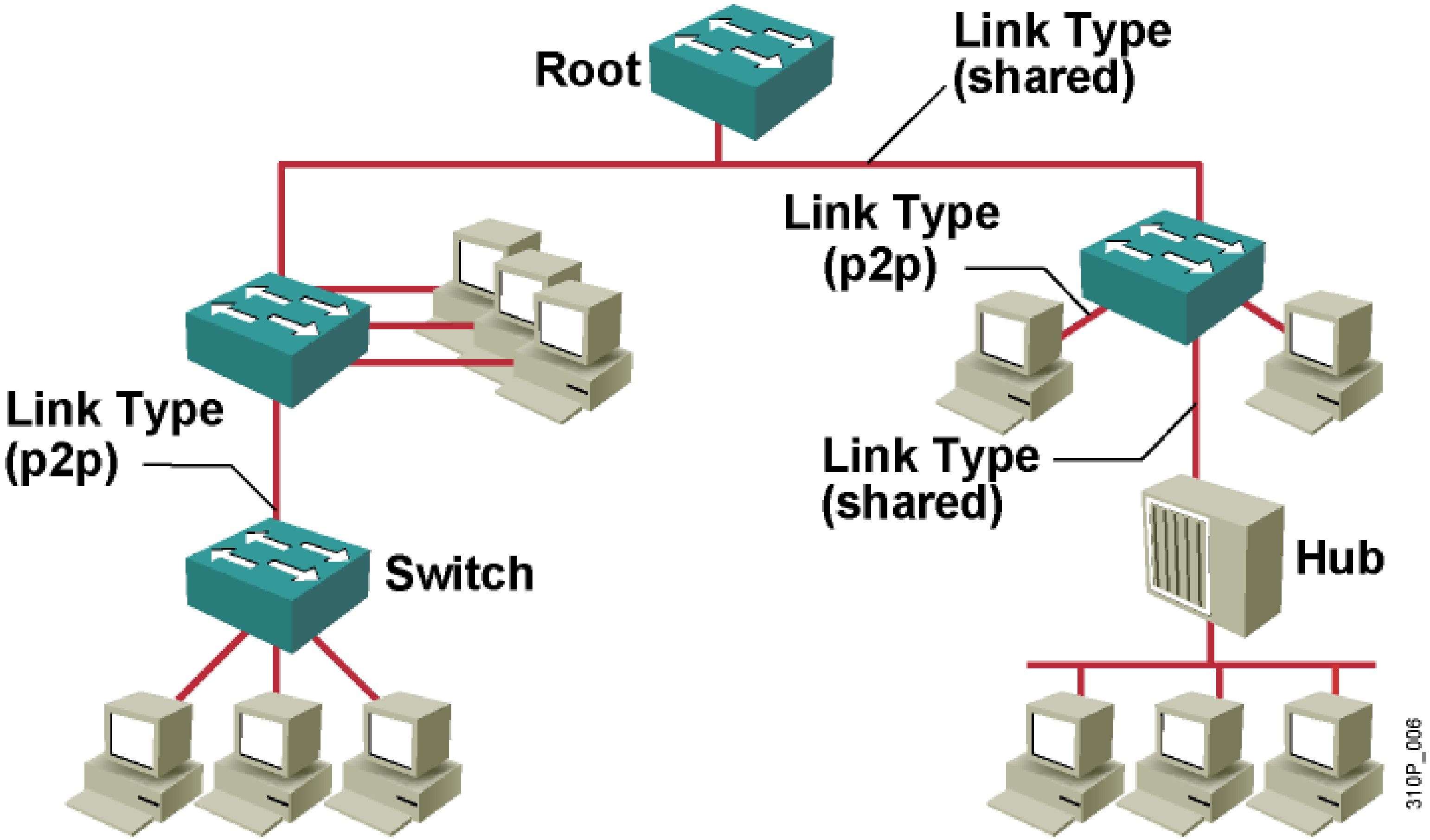
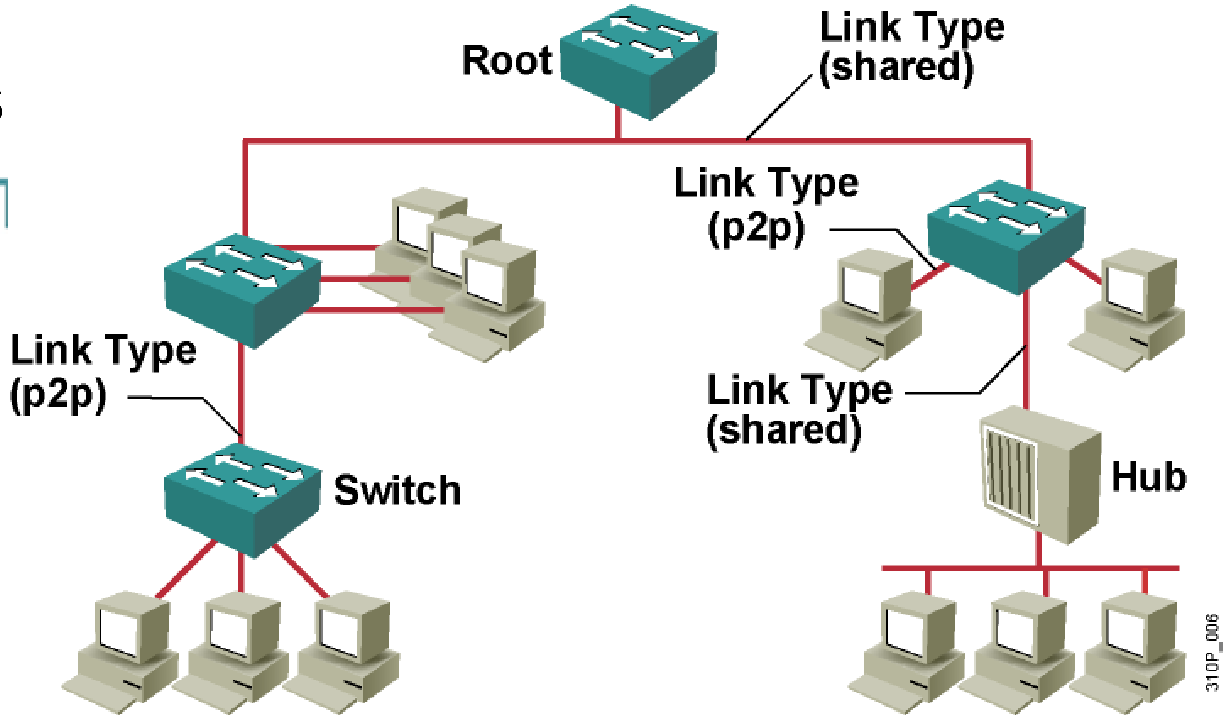


RSTP Link Types

- The link type can predetermine the active role that the port plays as it stands by for immediate transition to a forwarding state, if certain parameters are met.
- These parameters are different for **edge ports** and **non-edge ports**.
- **Non-edge ports** are categorized into two link types.
- Link type is automatically determined but can be overwritten with an explicit port configuration.
- **Point-to-Point links can transition immediately to forwarding state if another link goes down.**



RSTP Link Types

Link Type	Description
Point-to-point	•Port operating in full-duplex mode. •It is assumed that the port is connected to a single switch device at the other end of the link.
Shared	•Port operating in half-duplex mode. •It is assumed that the port is connected to shared media where multiple switches might exist.

Summary

STP: Summary

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Recall that switches go through three steps for their initial convergence:

STP Convergence

Step 1 Elect one Root Bridge: Lowest BID

Step 2 Elect Root Ports: Closest port to Root Bridge

Step 3 Elect Designated Ports: Best switch to Root Bridge

Also, all STP decisions are based on a the following predetermined sequence:

Five-Step decision Sequence

Step 1 - Lowest BID

Step 2 - Lowest Path Cost to Root Bridge

Step 3 - Lowest Sender BID

Step 4 – Lowest Port Priority

Step 5 - Lowest Port ID

STP: Summary

- **BID = Priority + MAC Address**
- **One Root Bridge** is elected per network
- **Every non-Root Bridge will select one Root Port!**
  - Switches Perspective: Port “closest” to Root Bridge
  - Smallest **Root Path Cost**, the cumulative cost of all links to the Root Bridge.
- Each **segment** in a bridged network has **one Designated Port**
  - Segment’s perspective: From a device on this segment, *“Which switch should I go through to reach the Root Bridge?”*
  - Chosen based on cumulative Root Path Cost to the Root Bridge.
  - The switch containing the Designated Port is referred to as the **Designated Bridge** for that segment.
- BPDUs are sent every 2 seconds by a switch

STP: Summary

- 50 Seconds from Blocking to Forwarding:
  - Blocking: Max Age 20 seconds
  - Listening: Forward Delay 15 seconds
  - Learning: Forward Delay 15 seconds
  - Forwarding

RSTP

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- Port States
  - Discarding
  - Learning
  - Forwarding
- Port Roles
  - Root
  - Designated
  - Alternate (NDP)
  - Backup
- Link Types
  - Point-to-point (Switch-to-Switch or Host-to-Switch)
  - Shared (Hub)

Algorhyme by Radia Perlman

I think I shall never see
A graph more lovely than a tree.

A tree whose crucial property
Is loop-free connectivity

A tree that must be sure to span
So packets can reach every LAN.

First the root must be elected.
By ID is is elected.

Least-cost paths from root are traced.
In the tree, these paths are placed.

A mesh is made by folks like me,
Then bridges find a spanning tree.

STP – Spanning Tree Protocol

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